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ABSTRACT

A program was conducted to design and test a prototype composite flap for the hydrofoil ship PCH-1. The flap was to be of the same configuration and equivalent in structural capability to the existing HY-130 steel flap. Test work was done to investigate a material system and to fabricate and test a feasibility component. Based on the data generated, a final design was developed and a full size flap was fabricated. The flap was instrumented and installed on the PCH-1 for service testing.

KEY WORDS

Graphite-Epoxy
Hydrofoil Flap
Service Testing
Nondestructive Evaluation
Fatigue Analysis
Design Analysis
Mechanical Properties

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1.0 INTRODUCTION AND SUMMARY

Graphite composites offer significant structural weight savings for high performance surface ships such as hydrofoils. To determine the practicality of these weight savings a representative structural component, a composite hydrofoil flap, was developed. The flap was subsequently installed on the PCH-1 for sea trials and will eventually be removed and fatigue tested to demonstrate its ability to comply with design life requirements. The development of the composite flap component included design and analysis studies, the evaluation of composite materials exposed to a marine environment, composite mechanical attachment tests, and the design, fabrication, and test evaluations of a feasibility component.

The program performed to develop the graphite/epoxy hydrofoil flap was accomplished under Naval Sea Systems Command, Contract N00024-76-C-4233, "Development of an Advanced Composite Hydrofoil Flap". This work was divided into three phases:

Phase I - Preliminary Design
Phase II - Final Design
Phase III - Prototype Fabrication

In Phase I, a preliminary design of the composite flap was developed, based on PCH-1 (Figure 1-1) requirements. The flap was designed to be interchangeable with the existing inboard starboard steel flap on the aft foil system. It consisted of one-half inch thick covers incorporating 36 plies of graphite/epoxy fabric at ±45 degrees clad with 10 mils of titanium. The covers were assembled to titanium substructure by both adhesive bonding and the installation of mechanical attachments. Preliminary design drawings of the selected design were prepared. These drawings showed the structural configuration, material selections, type of composite layup, and hinge details. Supporting analysis of this design was developed and showed compliance with ultimate stress failure criteria, fatigue panel stability, and joint requirements. Studies based on the detailed preliminary design

showed that under critical loading its deflections were equal to or less than the existing steel design, which indicated equivalent hydrodynamic performance. These results also showed that the composite design was 44 percent lighter than the existing steel design.

In Phase II, the design selected for further evaluation was finalized. Detailed shop drawings and a stress analysis were prepared. A full scale section of the crank end of the flap was fabricated and fatigue tested in salt water. Premature failures were encountered in the titanium details during these tests. Changes necessary to improve the fatigue characteristics of these details were incorporated in the final design. Specimens representative of the composite cover design were tested in the as-fabricated condition and after several months exposure in salt water. These tests included both static and fatigue in tension, compression, and shear. The results obtained demonstrated the ability of the composite covers to comply with the flap static load and fatigue life requirements. These tests were performed on torqued and blind mechanical fasteners in attachments representative of the flap construction. These results were also used to finalize the load transfer details in the final design. Nondestructive evaluation (NDE) studies were also performed. A titanium clad composite panel was fabricated with 12 types of built-in flaws. Several NDE techniques were evaluated by establishing their ability to find these flaws.

In Phase III, a prototype flap of the finalized design was fabricated. During fabrication, 52 strain gages and a water detection device were bonded on the inner cover surfaces. A calibration test was performed to obtain strain gage response readings as a function of load. The flap was then installed on the PCH-1 hydrofoil and is scheduled to undergo sea trial evaluations in the near future. These trials are expected to last 6 to 12 months and as a result, the accumulated flight loadings will be far short of the design life requirements. Therefore, after the trials have been completed, the flap will be removed and fatigue tested in a laboratory to demonstrate its compliance with a four times design life capability.

Problems were encountered during fabrication of the prototype flap. These problems were not associated with the composite elements, but were due primarily to the complex and close tolerance machining required on the titanium substructure. Design changes to simplify the substructure machining would be considered for production designs of this type of assembly.

Conclusions

a. The titanium clad T300/934 composite material system showed no loss of mechanical properties after exposures to 90 days in sea water and up to 11 months in an environmental chamber at 100 percent salt spray and 120°F.

b. A composite design of comparable size and structural capability offers weight savings of up to 44percent over a HY-130 welded flap.

c. Through bolts or bolts torqued into internal nut plates should be usd to attach heavy composite skins to the substructure whenever possible. Blind bolts resulted in premature failures during fatigue tests.

d. Through transmission ultrasonics was the best nondestructive testing technique investigated for inspecting the composite skins.

e. Based on preliminary design, analysis, and data obtained from specimen and component tests, the advanced composite flap developed in this program should provide adequate lifetime service in an hydrofoil service environment.

f. The producibility of a production flap based on the composite prototype design will be markedly improved, and would probably be competitive with the existing steel design as a result of the improved data base obtained from this program.

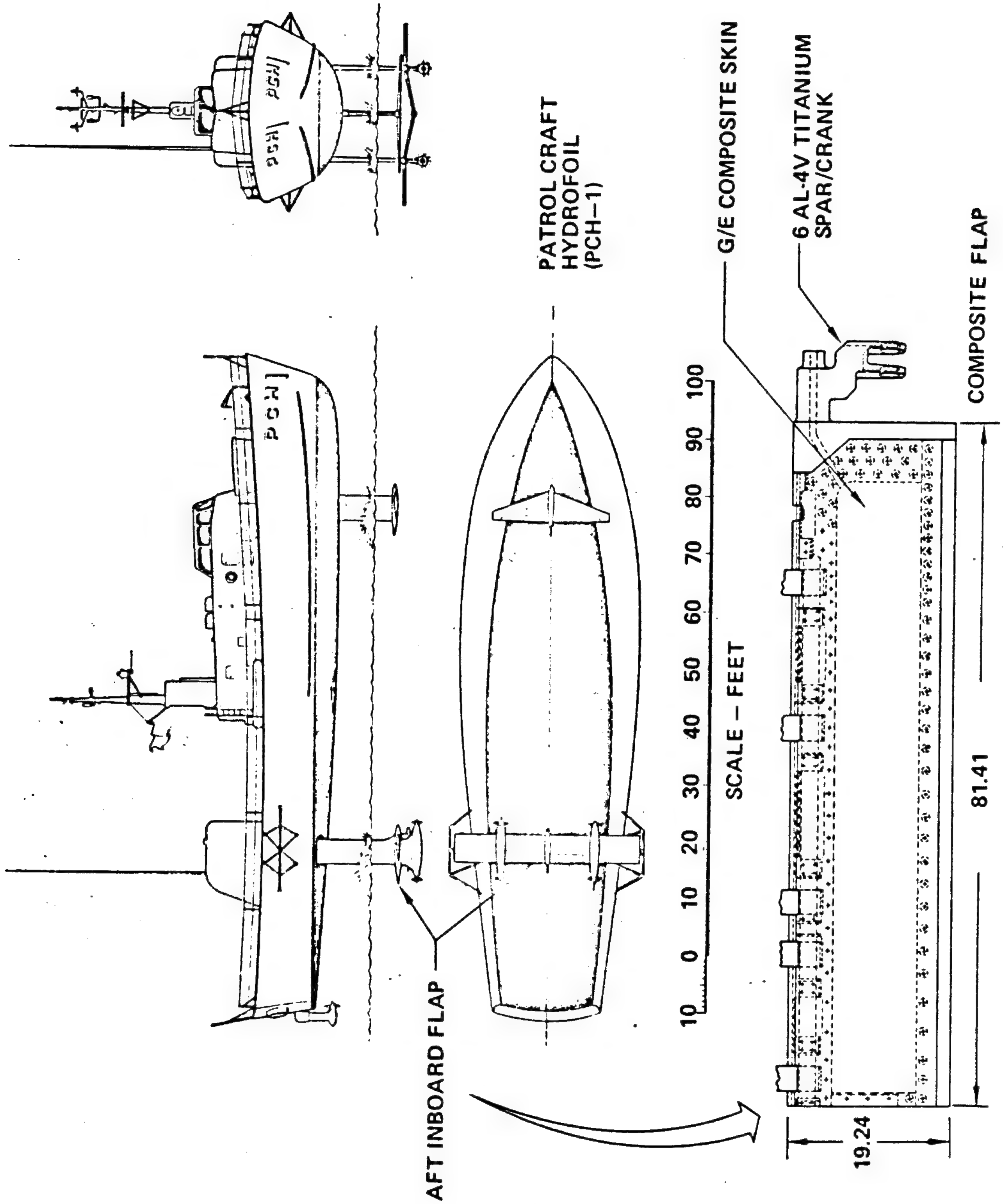


FIGURE 1-1 PATROL CRAFT HYDROFOIL (PCH-1) - COMPOSITE FLAP

2.0 COMPOSITE FLAP DESIGN STUDIES

Several composite hydrofoil flap designs were developed and evaluated to determine the most promising concepts that would warrant further consideration. These designs were based on the criteria used to design the inboard steel flap of the PCH-1 aft foil system. They were developed to be geometrically and functionally interchangeable with the existing steel flap. The composite flap concepts were designed to carry the same critical pressure and have the same or greater torsional and bending stiffnesses than the existing steel flap. The covers were designed to a constant thickness which permitted them to conform to a maximum chordwise deflection along their complete length. Also, the loads included the effects from a spanwise deflection induced by the foil. A summary of the design criteria used in the composite flap studies is shown in Table 2-1.

The composite flap designs that were developed incorporated composite upper and lower covers and a titanium crank-spar subassembly. The covers included designs which used GY-70, HMS, T300 tape, and T300 fabric graphite materials. All of these materials were oriented at ±45 degrees to provide adequate torsional stiffness, and cover thicknesses were established which provided characteristics which met chordwise deflection requirements. Analyses were also performed to determine maximum stresses under critical loading and resulting margins of safety. The material properties used in the above studies are summarized in Table 2-2.

The flap designs were all loaded with a critical pressure of 6300 psf, and the resulting deflections were compared to the existing steel flap. The composite covers were then resized to attain deflections equal to or less than the steel design. All of the composite designs required approximately the same cover thicknesses to match the chordwise stiffness of the steel design. These thicknesses varied from 0.517 inches to 0.528 inches, which were more than adequate to meet the required torsional stiffness characteristics. The maximum stresses and margins of safety were also determined for all of the designs. They were based on the combined stresses resulting from

TABLE 2-1

DESIGN CRITERIA - PCH-1 AFT INBOARD FLAP

CRITICAL UNIFORM PRESSURE LOAD	= 6300 PSF
TIP DEFLECTION	$\leq$ 0.53 INCHES [1]
MAXIMUM CHORDWISE DEFLECTION	$\leq$ 0.23 INCHES [1]
CONSTANT SKIN GAGE	
SPANWISE DEFLECTION	= 0.17 INCHES (INDUCED BY FOIL)

[1] EQUAL TO OR GREATER THAN THE EXISTING STEEL FLAP WHEN LOADED WITH THE CRITICAL UNIFORM PRESSURE.

chordwise bending, torsional shear, and spanwise bending due to deflections imposed by the foil. These results all showed positive margins. A summary of all of the design study deflection and strength data is shown in Table 2-3.

All of the composite designs established covers that were approximately 50 percent lighter than the existing steel covers. This resulted in an overall flap weight savings of approximately 44 percent. In general, the tape laminate cover designs have the greatest potential for saving weight, but they were also the most costly to produce due to the greater number of plies and increased handling difficulties.

As a result of the previous study, the design utilizing the T300 fabric was selected for further development. This concept was chosen because of both structural and cost considerations. The fabric provides a tougher and less strain sensitive material form than the more efficient graphite tapes. The design also incorporated a lower number of plies and the relative ease of handling the fabric provided a lower cost component.

TABLE 2-2

COMPOSITE MATERIAL PROPERTIES

MATERIAL		E_{11} (10^6psi)	E_{22} (10^6psi)	G_{12} (10^6psi)	ν_{12} (-)	F_{tu} (ksi)	F_{ty} (ksi)	F_{su} (ksi)	t_{ply} (inches)
HY-130		29	29	11.2	0.25	150	130	78	
GY-70/934	1	3.0	3.0	10.6	0.90	23	15	36	.006
HM-S/934	1	3.0	3.0	6.9	0.79	23	15	36	.0085
T300(TAPE)/934	1	3.2	3.2	4.9	0.72	23	15	36	.0055
T300(FABRIC)/934	1	3.0	3.0	4.7	0.72	23	15	36	.013
TITANIUM 6AL-4V		16.0	16.0	6.2	0.31	134	126	79	

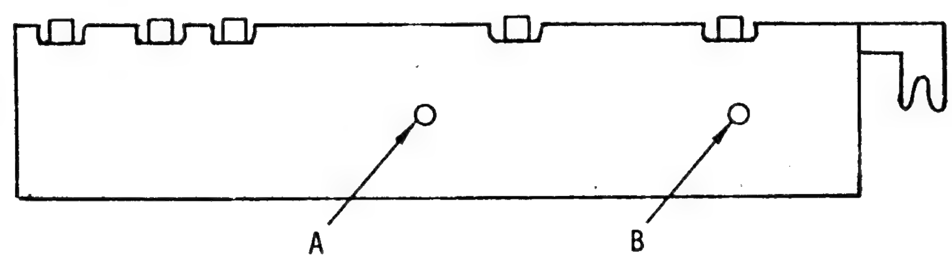
1 ± 45 Laminate, elastic properties are calculated, allowable strengths are estimated from A-Basis Data for T300(FABRIC)/934 materials tests.

TABLE 2-3

PCH-1 COMPOSITE INBOARD FLAP DESIGN STUDIES

MATERIAL	DESIGN THICKNESS (PLIES) (INCHES)	CRITICAL DESIGN CONDITION	TIP DEFLECTION, TORSION (INCHES)	COVER DEFLECTION, PRESSURE (INCHES)	MAXIMUM STRESS				APPROX MARGIN OF SAFETY M. S.
					LOCATION [1]	CHORDWISE BENDING (ksi)	TORSIONAL SHEAR (ksi)	SPANWISE BENDING (ksi)	
HY-130	.200 (min. gage)	Strength	0.53	0.23	A B	107.2 107.2	10.3 20.6	21.7 0	+.01 +.02
GY-70/934 [1]	88 .528	Pressure	.212	0.23	A B	15.4 15.4	3.9 7.8	2.2 0	+.13 +.12
HM-S/934 [1]	62 .527	Pressure	.326	0.23	A B	15.4 15.4	3.9 7.8	2.2 0	+.13 +.12
T300T/934 [1]	94 .517	Pressure	.469	0.23	A B	16.0 16.0	4.0 8.0	2.4 0	+.09 +.08
T300F/934 [1]	40 .520	Pressure	.485	0.23	A B	15.9 15.9	3.9 7.9	2.2 0	+.10 +.09

[1] ± 45 Laminates



3.0 PRELIMINARY DESIGN

A preliminary design of the composite flap on the aft foil system of the PCH-1 hydrofoil was developed. It was based on the graphite fabric cover concept developed in the previous design studies (Section 2.0). This concept was modified to incorporate 10 mil thick titanium cladding on the inner and outer surfaces of the covers to improve their cavitation and erosion resistance. The number of plies in the original concept were reduced from 40 to 36 because of the additional capability provided by the titanium cladding. During the preliminary design effort drawings were prepared in greater detail, supporting analysis was performed, and a weight comparison was made between the composite design and the existing steel design. These areas will be discussed in the following sections.

3.1 DESIGN

The preliminary design was based on the same criteria used for the design of the existing steel flap and as described in the previous section (2.0). It incorporated graphite/epoxy covers clad with 10 mil thick titanium and a titanium crank-spar substructure assembly. Details of the preliminary design are shown in Figures 3-1a and 3-1b.

The composite flap was designed to be completely interchangeable with the existing inboard starboard steel flap on the aft foil. It was 81.44 inches long and had a chord length of 19.24 inches. It was to be attached to the foil at five hinge points and a crank stub bearing. Its upper and lower surface panels consisted of 36 plies of graphite/epoxy fabric oriented at ±45 degrees and 10 mil thick titanium bonded to their surfaces. The number of fabric plies and their orientation were established by cover chord deflection and torsional stiffness requirements. The covers had a constant thickness of approximately 0.50 inches and were contoured to a required hydrodynamic shape. The titanium cladding was incorporated to provide an environmental barrier to improve resistance to moisture absorbtion, cavitation, and erosion.

The crank and spar substructure used in the composite flap design was made of 6Al-4V titanium. The crank and two spar sections were to be assembled by electron beam welding.

The covers would be installed on the titanium spar-crank substructure by both bonding and the installation of mechanical fasteners. The details would be pre-assembled, all the attachment holes drilled, all parts cleaned, and all the metal surfaces primed. The details then would be reassembled with film adhesive in place and the assembly processed through an adhesive cure. The mechanical features would then be installed to complete the assembly.

3.2 ANALYSIS

An analysis of the composite flap was performed to identify the critical areas of the design and to determine its critical and operating stress levels. The preliminary design was based on both load and stiffness considerations. These criteria are specified in Table 2-1.

The composite flap was analyzed using a finite element analysis and strength of materials calculations for loads and stresses. The results indicated that the static deflections were within allowable limits, and that material and joint stresses had adequate margins of safety for the static critical loads. A preliminary fatigue analysis based on a representative sample of PCH-1 voyage data, indicated that the operating stresses were well within the fatigue strength of the materials used in the preliminary design.

3.2.1 LAMINATE STIFFNESS PROPERTIES

The flap cover panel design consisted of 36 plies of T300/934 fabric at ±45 degrees with .010 inch thick titanium (6Al-4V) cladding on both sides. The cladding was added primarily for environmental protection, but it also served to stiffen the composite in plate bending. To fully account for the effectiveness of the laminated covers, the titanium properties were included in the calculations for membrane and bending stiffness. The resulting

values were used as plate element properties for the NASTRAN analysis.

The material properties used were:

6Al-4V Titanium	T300/934 Fabric
$E = 16.0 \times 10^6$ psi	$E11 = 10.2 \times 10^6$ psi (Warp)
$G = 6.2 \times 10^6$ psi	$E22 = 9.6 \times 10^6$ psi (Fill)
$\nu = 0.31$	$G12 = 0.87 \times 10^6$ psi
t_{ply} = .010 inch (Nominal)	$\nu 12 = .63$
	t_{ply} = .013 inch (Nominal)

The titanium properties were taken from the Boeing Design Manual and the T300/934 properties were developed from tests performed at Boeing.

The material properties and the laminate construction, [.010 Ti/$\pm 45_{36}$/.010 Ti] were input to the laminate analysis code - LAC. LAC transformed the T300/934 properties to the warp and fill ±45 degrees orientations and determined the composite plate stiffness parameters E_x, E_y, G_{xy}, ν_{yx} for the membrane and D_x, D_y, D_{xy}, ν_{yx} for bending stress resultants.

3.2.2 FINITE ELEMENT ANALYSIS FOR DEFLECTION

A NASTRAN finite element model of the PCH composite flap was jointly developed by Boeing and DTNSRDC. Node points and elements were selected to provide a good estimate of the flap deflections under load and to provide reasonable estimates of the internal loads and stresses. Figure 3-2 is a sketch of the nodel network used in the model.

Three loading conditions were used in the analysis: distributed pressure, uniform pressure, and distortion of the flap imposed by the foil at critical load. The distributed pressure accounted for the center-of-pressure located at 0.4 of the flap chord for the critical load of 6300 psf. The maximum torque produced by this hydrofynamic loading was 412 inch-kips. The

uniform pressure load simulated a static test condition which applied a uniform critical load of 6300 psf over the entire flap chord. The maximum torque produced by this loading was 507 inch-kips. The PCH-1 Mod 1 aft flap critical hinge moment calculated from the control-system-linkage was 467.5 inch-kips. This was about 13 percent higher than the maximum hydrodynamic loading. This difference was typical of control system design, since there is some attenuation associated with the linkage. The critical design condition used for the flap analysis was the maximum hydrodynamic loading plus flap distortion due to foil bending.

A plot of the trailing edge deflections of the composite flap versus the flap station is shown in Figure 3-3. Flap Station 0 is located at the crank end of the flap. The deflected shape of the steel flap was included as a dashed line and as shown, the composite flap has equal or better stiffness in torsion than the steel flap. Curves show some small differences in the deflected shape of the trailing edges; however, the composite flap had slightly less deflection over the total span.

The critical pressure load, 6300 psf, caused local deformations in the cover which had an effect on the hydrodynamic lift characteristics of the flap. Therefore, the deformed shapes of the composite and steel flaps were determined for the chordwise section at flap station 54. Figure 3-4 shows the flap's theoretical lower surface contour as well as the deformed contours of both the steel and composite flaps. As shown, the composite cover holds its contour better than the steel cover.

Based on the calculated trailing edge deflections and the contour deformations under critical load, it was concluded that the composite flap had equal or better hydroelastic performance than the existing steel design.

3.2.3 COVER STRENGTH ANALYSIS

The NASTRAN finite element model was used to calculate the stresses in the composite covers. Since the material properties used in the NASTRAN plate

elements were "composite" values for the clad laminate, the NASTRAN stresses were converted to either titanium or T300-934 stresses to determine strength margins.

The results of the NASTRAN analysis indicate that the maximum stresses occurred in the lower cover. The maximum "composite" stresses were approximaterly 14 ksi in both tension and compression. The maximum shear stress was 16 ksi and occurred at the crank attachment. The normal stresses in the upper cover were about half the stresses in the lower cover and were not critical.

Figure 3-5 is a sketch of the NASTRAN analysis model. The shaded areas indicate the highly stressed areas of the lower cover. Also, the areas of maximum bending stress (due to the 6300 psf pressure load) and maximum shear stress have been shown in more detail.

Factors were used to convert the maximum "composite" stresses to stresses in the cover materials. They were based on the strains determined in the NASTRAN analysis and a constant strain relationship assumed for plane stress.

Critical biaxial stresses were calculated at two locations: the point of maximum bending stresses and the point of maximum shear stress.

The maximum bending stresses occurred at flap station 55 in the lower cover on the outside surface. Both the chordwise and spanwise stresses were in compression (see Figure 3-5). At that point the "composite" stresses were:

$$\sigma_1 = -13.5 \text{ ksi}$$

$$\sigma_2 = -13.0 \text{ ksi}$$

$$\tau_{12} = 3.8 \text{ ksi}$$

The calculated titanium stresses were:

$f_x = -29.3$ ksi

$f_y = -26.6$ ksi

$f_{xy} = 4.9$ ksi

Titanium 6Al-4V annealed allowable stresses are:

$F_{cy} = 132$ ksi

$F_{sy} = 76$ ksi

The calculated T300/934 stresses on the outer ply next to the titanium were:

$f_x = -10.7$ ksi

$f_y = -10.3$ ksi

$f_{xy} = 3.9$ ksi

T300/934 allowable yield stresses are:

$F_{cy} = 18$ ksi

$F_{sy} = F_{su} = 36$ ksi

Using the combined stress equation for margin-of-safety,

$$M.S. = 1 - \left(\frac{f_x}{F_{cy}}\right)^2 - \left(\frac{f_y}{F_{cy}}\right)^2 - \left(\frac{f_{xy}}{F_{sy}}\right)$$

The margin-of-safety for yielding ofthe T300/934 was +0.21 at the critical loading.

The maximum shear stresses occurred near the crank end on the outer surface of the lower cover at the location shown in Figure 3-5. The composite stresses were:

$\sigma = +11.5$ ksi

$\sigma_2 = 6.4$ ksi

$\tau_{12} = 16.2$ ksi

The calculated titanium stresses are low and the T300/934 stresses are:

$f_x = 8.9$ ksi

$f_y = 5.2$ ksi

$f_{xy} = 16.9$ ksi

The T300/934 allowable yield stresses are:

$F_{ty} = 15$ ksi

$F_{sy} = 36$ ksi

The margin-of-safety for yielding is:

$$\text{M.S.} = 1 - \left(\frac{8.9}{15}\right)^2 - \left(\frac{5.2}{15}\right)^2 - \left(\frac{16.9}{36}\right) = +0.06$$

Based on these data it was concluded that the preliminary design had adequate strength for the critical load case without exceeding the yield strength of either the titanium cladding or the T300/934 fabric laminate.

3.2.4 PANEL INSTABILITY ANALYSIS

The composite flap did not use intermediate ribs to support the covers. A simple analysis of panel instability was made to verify the design. The critical load produced a maximum torque of 467.5 inch-kips. At the crank attachment this produced a critical shear flow of:

$$N_{xy} = \frac{M_t}{2[A]} = \frac{467{,}500 \text{ in-lb}}{2 \times 46.03 \text{ in}^2} = 5080 \text{ lb/in}$$

The total composite thickness was 0.488 inches and the unsupported span from spar to trailing edge was 17 inches. Assuming a square panel aspect ratio and using a critical shear load for a flat, simply supported orthotropic plate as a conservative estimate, the critical shear load was:

$$N_{xycr} = \frac{10.4\ K_s G_s\ 4\sqrt{\left(\frac{D_1}{E_x}\right)\left(\frac{D_2}{E_y}\right)^3}}{6^2}$$

$$N_{xycr} \geqq 24{,}000 \text{ lb/in}$$

Therefore, the covers were very stable in torsion.

3.2.5 TITANIUM SPAR-CRANK ASSEMBLY ANALYSIS

The spar and crank assembly was a 6Al-4V titanium weldment as detailed in Figure 3-1b. In the NASTRAN analysis the spar was modeled using plates for the shear web and chords. The crank was not included in the NASTRAN analysis.

The primary loads on the spar were bending due to flap distortion, reaction of the hinge loads, and distribution of the hinge loads to the cover. The maximum spar stresses from the NASTRAN analysis were:

Maximum chord stress = 27.5 ksi - tension
Maximum web stress = 29.2 ksi - shear

The titanium 6Al-4V allowables were:

$$F_{ty} = 126 \text{ ksi}$$
$$F_{sy} = 76 \text{ ksi}$$

∴ Margins of safety were high.

3.2.4 FATIGUE ANALYSIS

The objectives of this preliminary fatigue analysis were to establish reasonable design life goals for and typical operating stresses in the composite flap. Potential failure mechanisms and the allowable operating

stresses for critical design details were to be determined through testing later in the program.

The design life data was developed which was based on the evaluation of PCH-1 log data for voyages occurring between March 1973 and January 1976. These log data were scaled upward from the 34 month data to a design life of ten years. Estimated fatigue life requirements for the composite flap were also developed which were based on a small sample of real time strain gage data for the inboard, starboard flap. The strain gages were located on control system linkage push rods and were calibrated to measure the torque applied to the flap crank arm. The critical design hinge moment on the control system side of the flap was 467.5 kip-inches. The maximum load level by seastate was based on this value. To simplify the analysis, fatigue life requirements assumed a scatter factor of 4 as a conservative estimate for the total number of load cycles per expected use in each seastate.

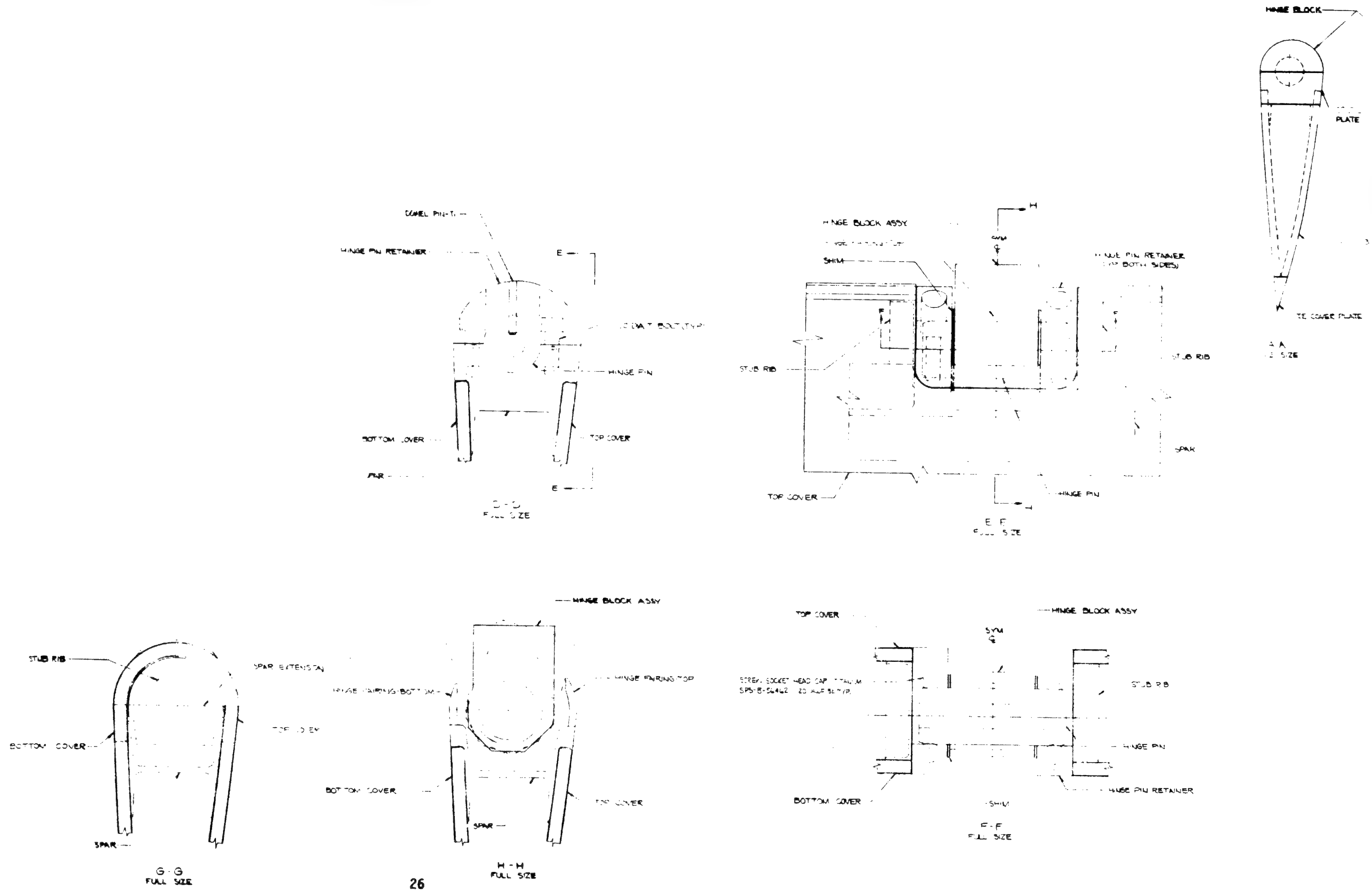
Figure 3-6 summarizes the available material fatigue data and the fatigue life requirements for the flap cover materials. The composite flap used T300/934 fabric in a ±45 layup. All available fatigue data for this material are for axial loading. The flap maximum fatigue stresses were primarily in shear and these cover stresses have been plotted as principal normal stresses. The cover stresses are shown as total cumulative blocks for each seastate. Fatigue data for welded 6Al-4V titanium are also included in Figure 3-6 since the composite design uses a titanium spar welded to a titanium crank. Positive margins were shown (Figure 3-6) between the fatigue requirements and the allowable stresses for all the composite flap materials.

3.3 WEIGHT SUMMARY

The weights of the existing steel and the preliminary design of the composite flap were determined. This data was summarized in Table 3-1. As shown, the major items contributing to the overall flap weight are the crank, hinge blocks, spar, and covers. Two weights were developed for the

steel crank. One as it presently exists on the steel flap and a second which was based on refining it to the same extent as the titanium crank. The titanium spar was heavier than the steel spar. Additional titanium material was incorporated by adding flanges to provide sufficient bonding surfaces for assembly, and several integral boss areas were included for the bearing installations. The titanium clad composite covers were twice as thick as the steel covers (½" versus ¼") but because of the lower density, the composite covers weigh approximately one-half as much.

The total weight of the existing steel flap was 485 pounds. This could have been reduced to 423 pounds by indorporating the more refined crank. A comparison of the composite flap shows that it was 44 percent lighter than the existing steel flap which was reduced to 36 percent when compared to the steel design with the refined crank.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TOP COVER
SPAR
FULL SIZE
HINGE BLOCK ASSY
SHIM
STUB RIB
HINGE PIN RETAINER
TYP BOTH SIDES)
SPAR
TOP COVER
HINGE PIN
E-E
STUB RIB
SPAR EXTENSION
BOTTOM COVER
SPAR
G-G
FULL SIZE
HINGE BLOCK ASSY
HINGE FAIRING-BOTTOM
HINGE FAIRING TOP
BOTTOM COVER
SPAR
TOP COVER
H-H
FULL SIZE
TOP COVER
HINGE BLOCK ASSY
SYM
STUB RIB
HINGE PIN
BOTTOM COVER
HINGE PIN RETAINER
SHIM
F-F
FULL SIZE

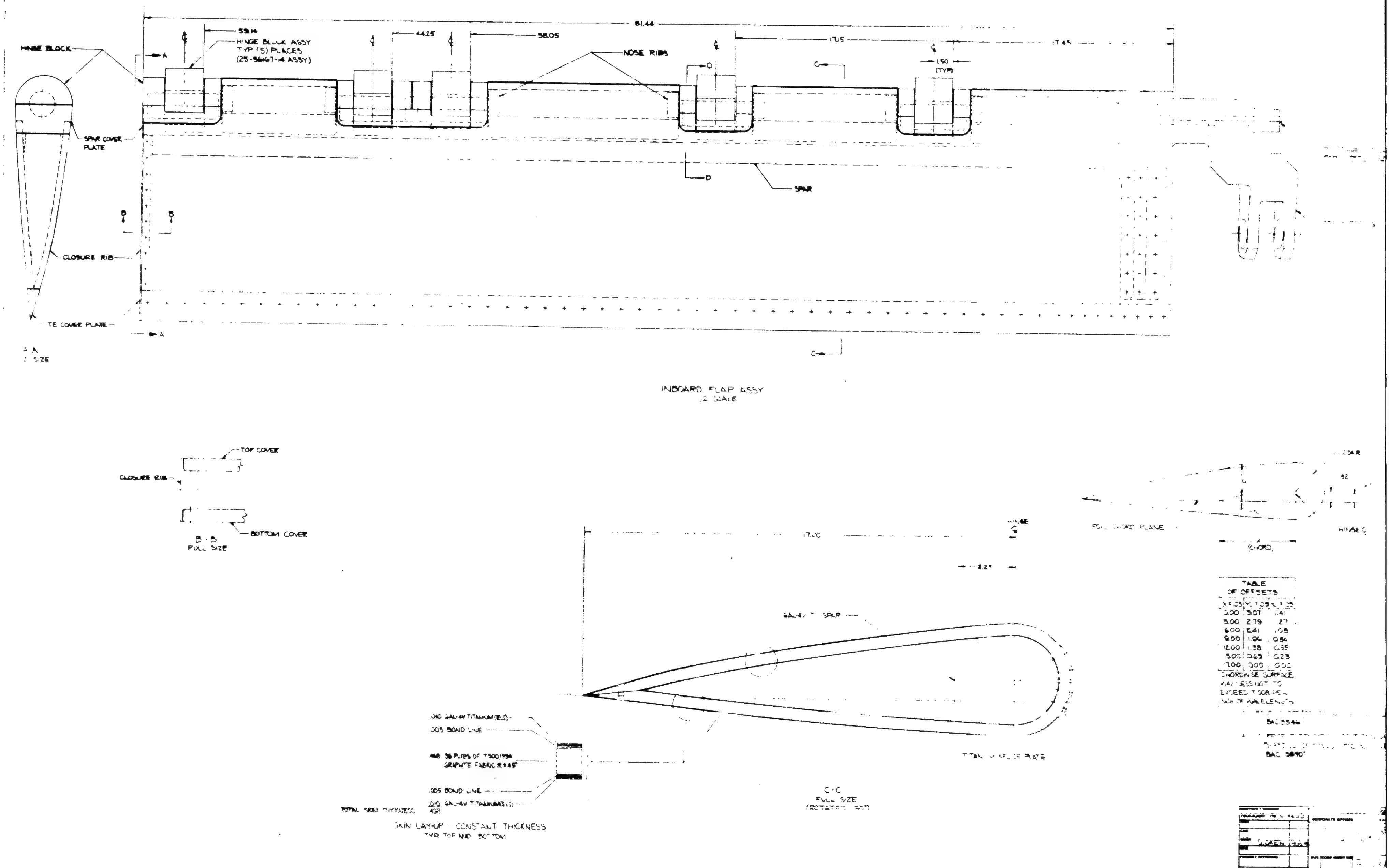


FIGURE 3-1a COMPOSITE FLAP PCH 1 ASSEMBLY

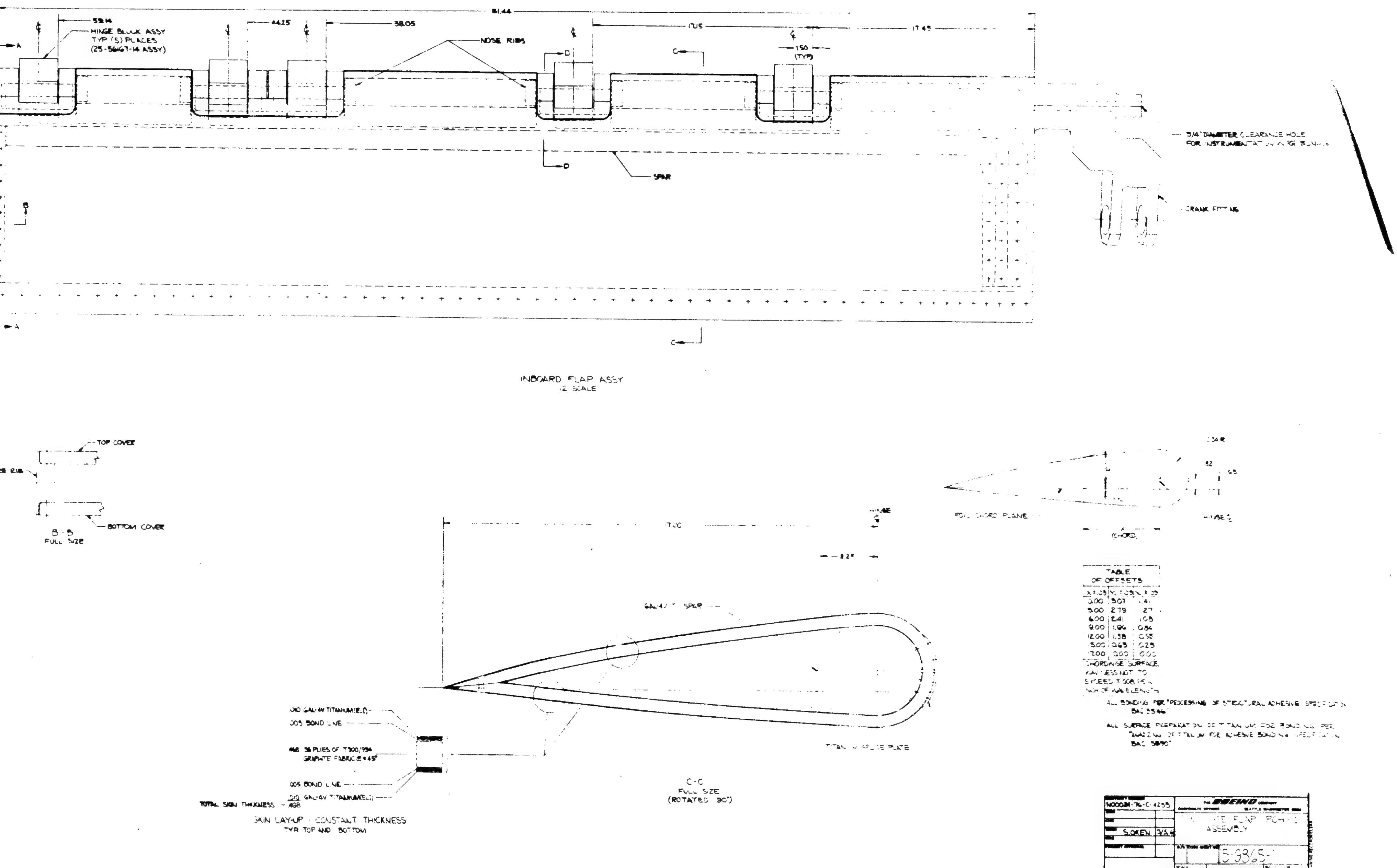
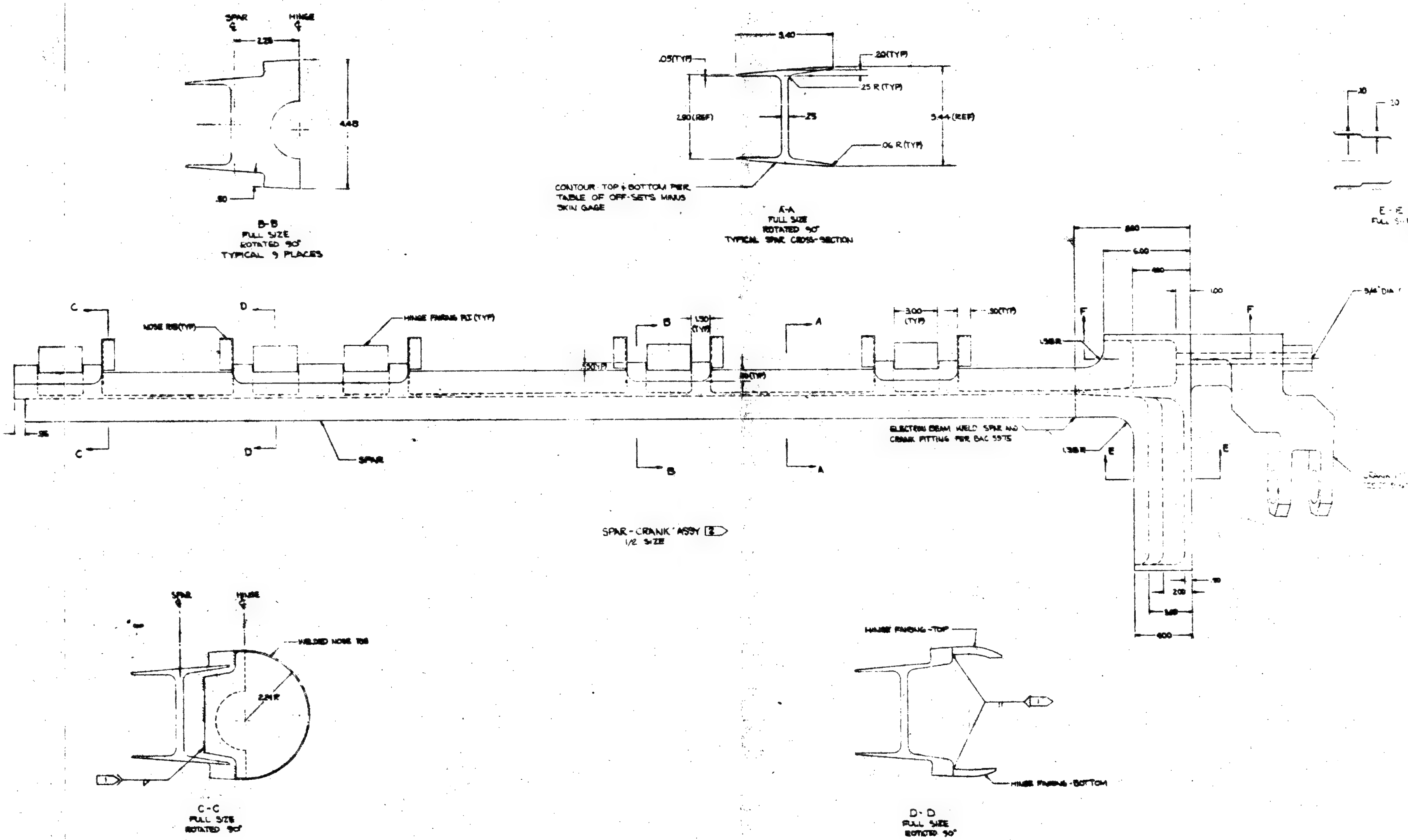


FIGURE 3-1a COMPOSITE FLAP PCH-1 ASSEMBLY (5-93... 1 SHEET 1)


SPAR ℄
HINGE ℄
2.25
4.48
.80
B-B
FULL SIZE
ROTATED 90°
TYPICAL 9 PLACES
3.40
.05(TYP)
.20(TYP)
.25 R (TYP)
2.80 (REF)
.25
3.44 (REF)
.06 R (TYP)
CONTOUR TOP & BOTTOM PER TABLE OF OFF-SETS MINUS SKIN GAGE
A-A
FULL SIZE
ROTATED 90°
TYPICAL SPAR CROSS-SECTION
E-E
NOSE RIB (TYP)
HINGE FAIRING FIT (TYP)
3.00 (TYP)
.30(TYP)
1.30 (TYP)
1.00
6.00
ELECTRON BEAM WELD SPAR AND CRANK FITTING PER BAC 5975
SPAR
SPAR-CRANK ASSY
1/2 SIZE
2.00
WELDED NOSE TAB
2.24 R
C-C
FULL SIZE
ROTATED 90°
HINGE FAIRING-TOP
HINGE FAIRING-BOTTOM
D-D
FULL SIZE
ROTATED 90°

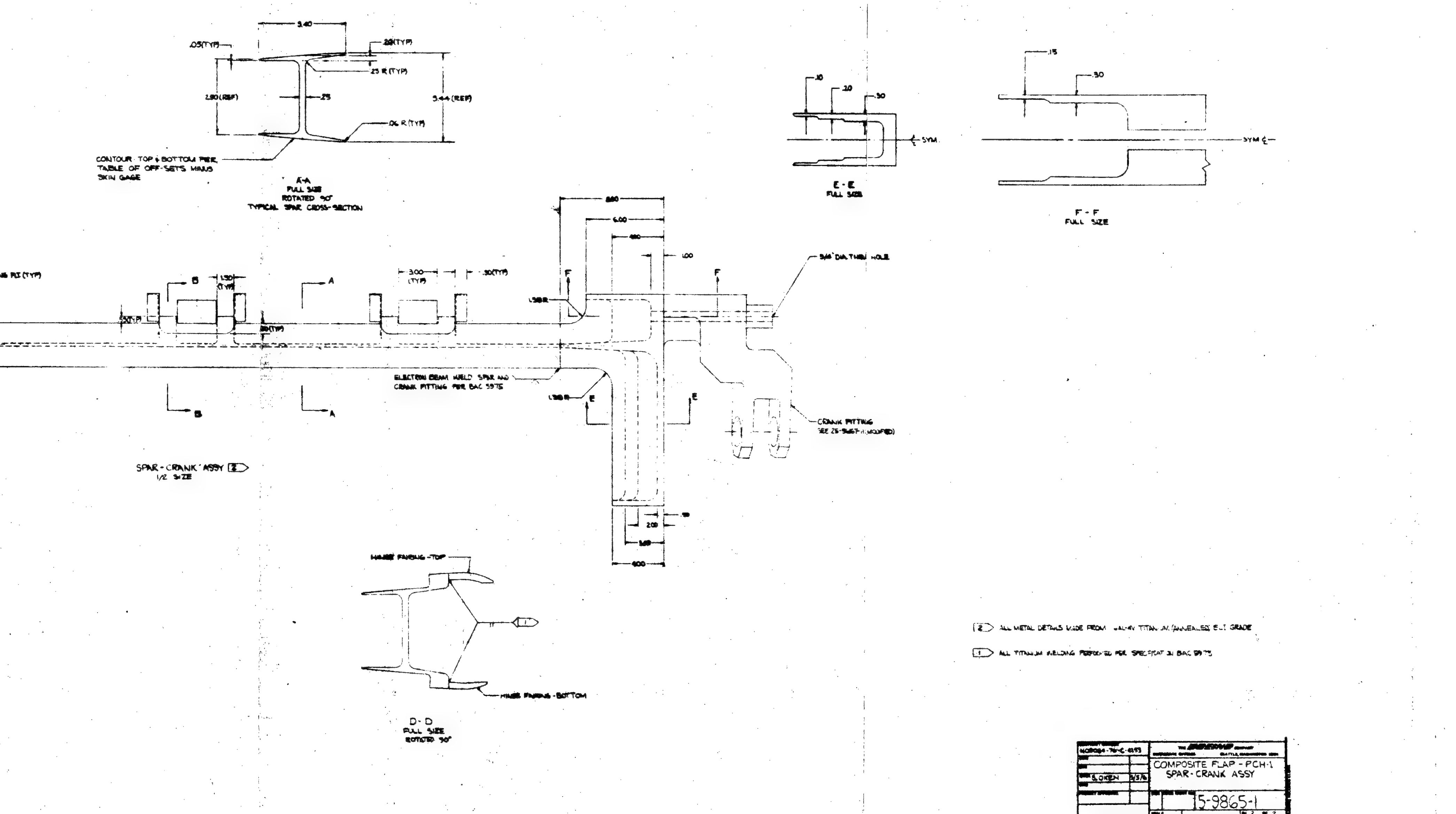


FIGURE 3-1b COMPOSITE FLAP PCH-1 ASSEMBLY (5-9865-1 SHEET 2)

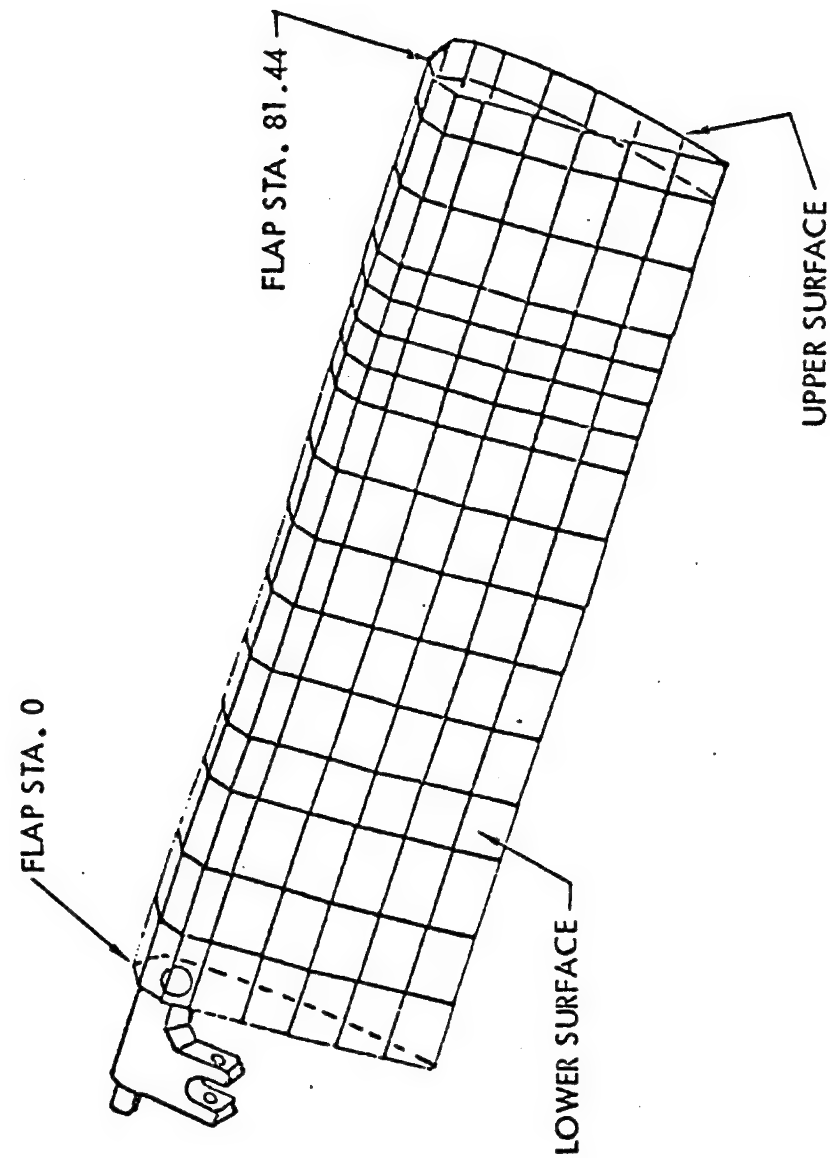


FIGURE 3-2 NASTRAN MODEL OF PCH FLAP

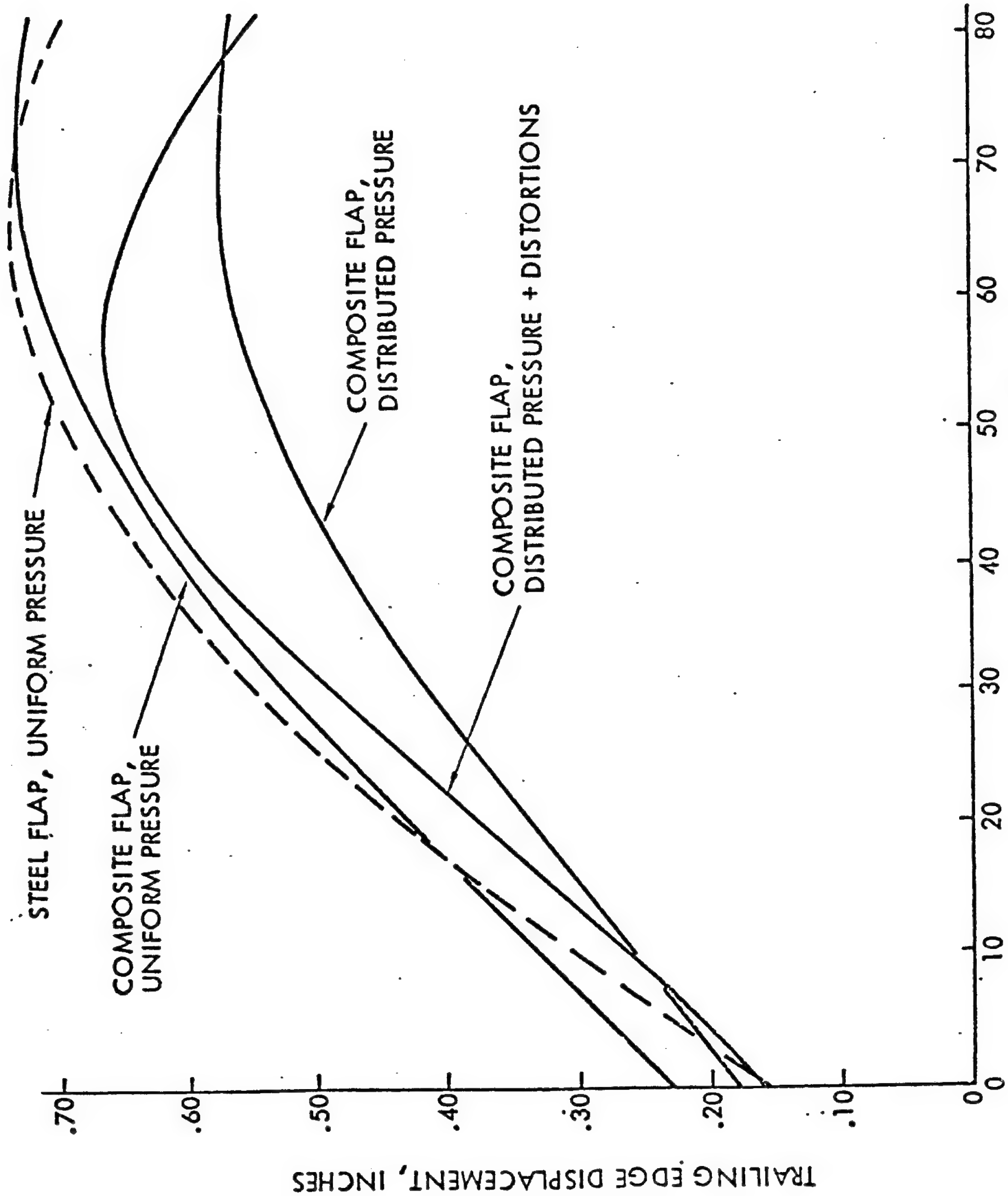


FIGURE 3-3 PREDICTED FLAP DEFLECTIONS AT THE TRAILING EDGE

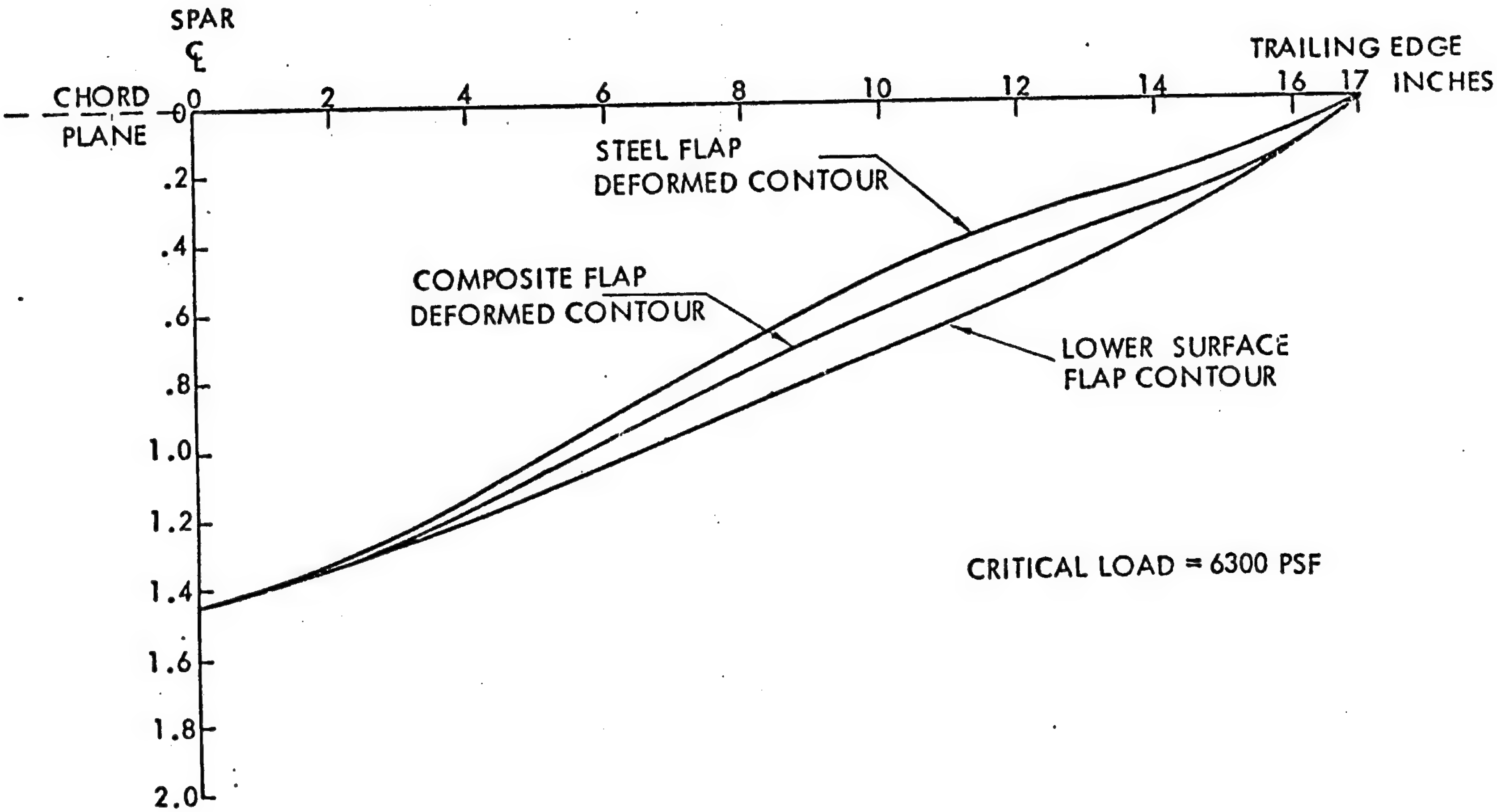


FIGURE 3-4 FLAP CONTOUR DEFORMATIONS DUE TO PRESSURE AT F.S. 54

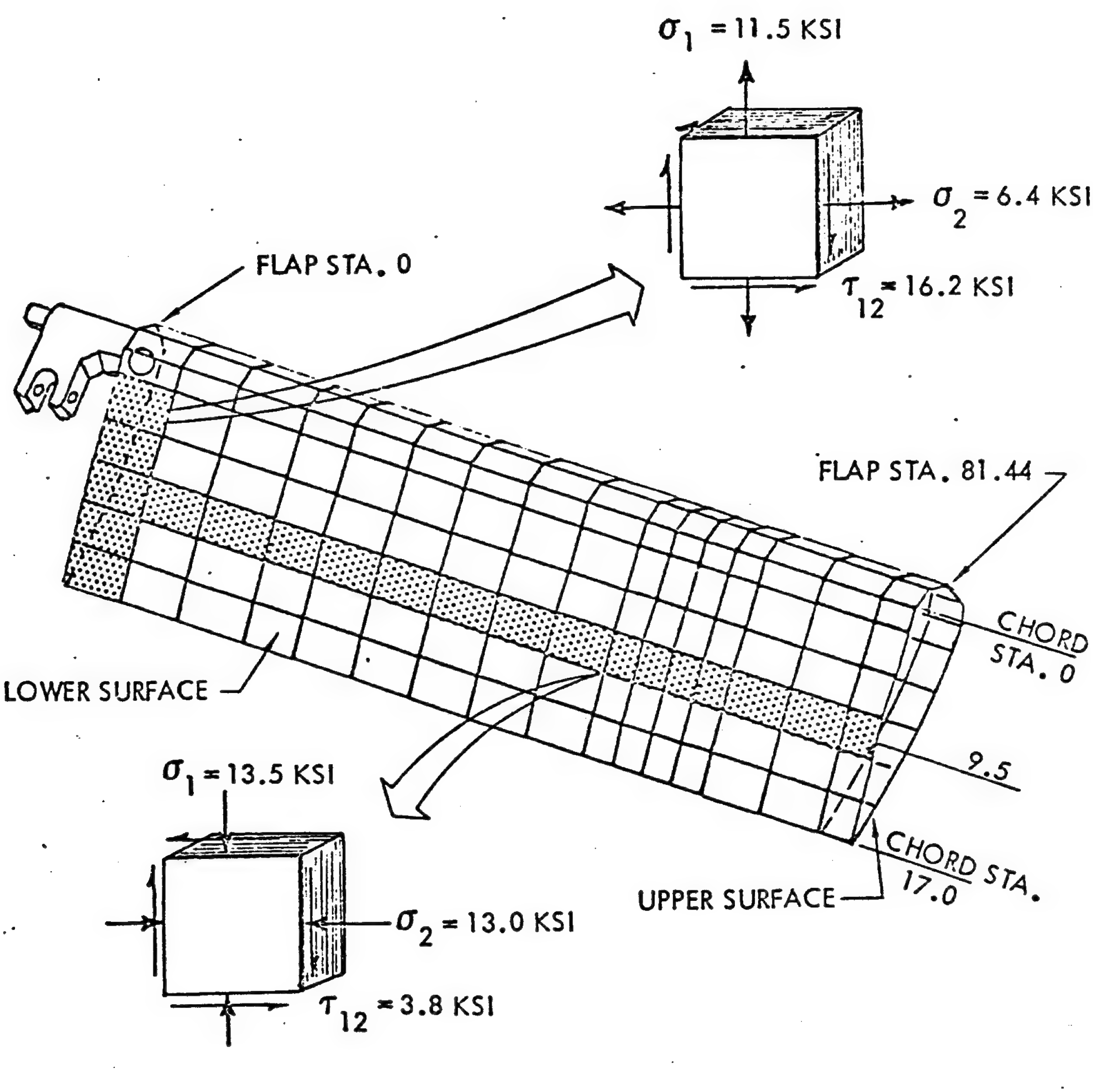


FIGURE 3-5 CRITICAL STRESS AREAS OF THE COMPOSITE FLAP

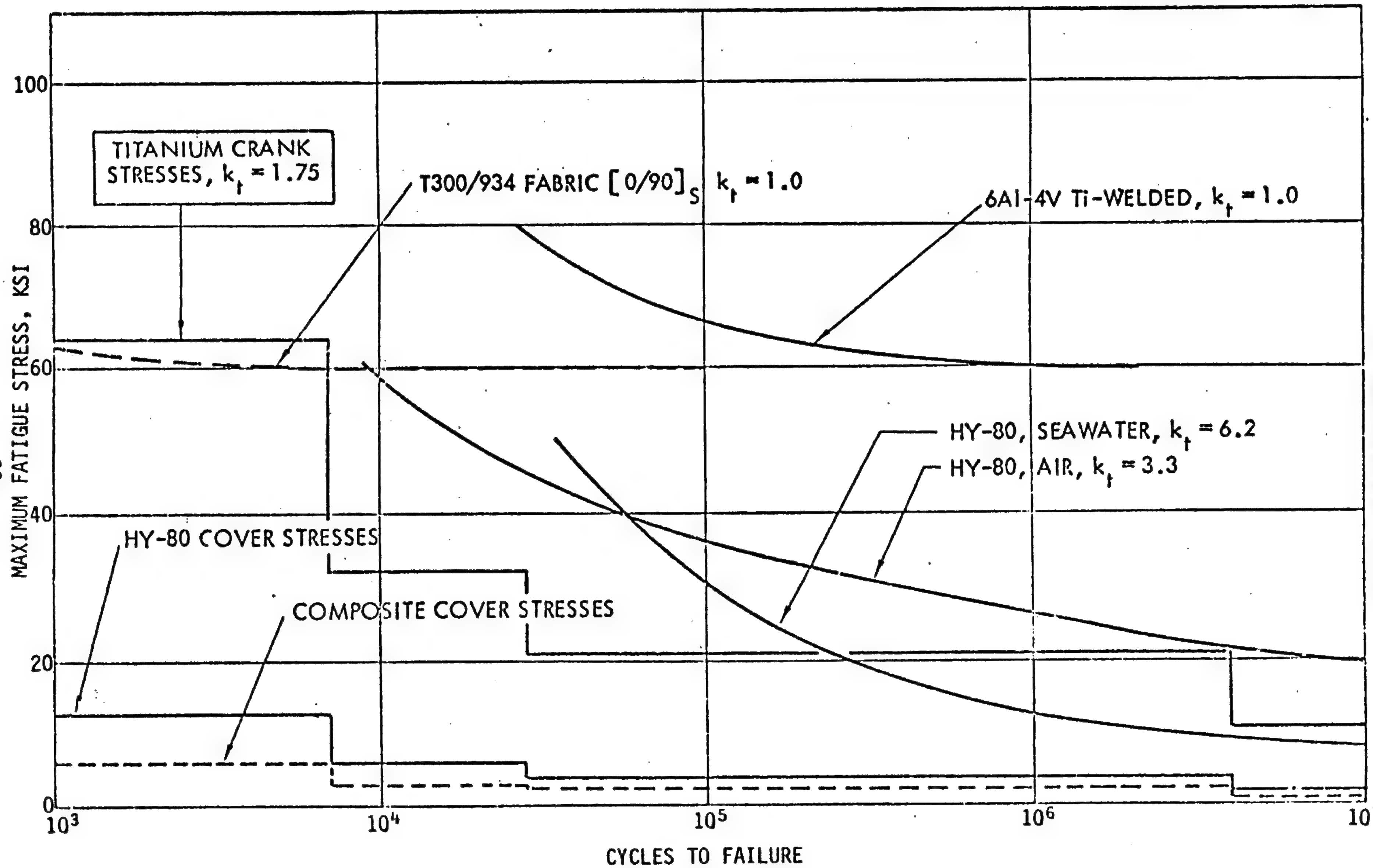


FIGURE 3-6 PCH FLAP FATIGUE ANALYSIS FOR COVERS AND TITANIUM CRANK

TABLE 3-1

FLAP WEIGHT COMPARISONS

	EXISTING STEEL DESIGN (Pounds)		COMPOSITE CLAD DESIGN (10 Mil Ti and 36 Plies Gr/E) (Pounds)	
MOVABLE	(442)	[380]	(228)	
Crank Fitting	149	[87]	38	
Hinge Pins	22		22	
Hinge Blocks	45		29	
Main Spar	18		34	
Covering	198		97	
Other	10		8	
FIXED	(43)		(43)	
Hinges	32		32	
Bearing Holder	11		11	
TOTAL	485	[423]	271	
WEIGHT SAVING (PERCENT)			44	[36]

Numbers in Square Brackets [ ] are based on the existing steel design with an improved steel crank fitting.

4.0 MATERIAL TESTING

To insure that the titanium clad T300/934 fabric (Fiberites designation HMF 330C/34), cover concept used in the flap design would meet design requirements under hydrofoil environmental conditions, a test program was performed. The specimens used were made of eight plies of T300/934 fabric oriented at ±45 degrees and 10 mils of titanium cladding bonded on the laminate surfaces. One-half ofthe specimens were tested in the as-fabricated condition and one-half were placed in Puget Sound salt water for 90 days prior to testing. The composites in the exposed specimens were directly in contact with the salt water at their edges, at holes and fracture slots. Both exposed and unexposed specimens were tested statically and in fatigue. The exposed specimens were tested in salt water and their fatigue rate was limited to 6 Hz to permit salt water to infiltrate micro-cracks in the composites, should they develop.

Several of the clad eight ply specimens were tested statically. Some were tested in the as-fabricated condition and some after 90 days exposure to salt water in Puget Sound. A summary of these results is shown in Table 4-1. This data showed that no significant loss in properties was caused by the 90 day salt water exposure. No corrosion or deterioration of the Ti-to-composite bond was noted.

Specimens were tested in tension fatigue using a stress ratio of R = -.05. They were tested with and without holes,and in both the unexposed condition and after exposure to salt water for 90 days. The non-exposed specimen tests were conducted at 30 Hz in a Sonntag SF-10 fatigue test machine and the exposed specimens were fatigued at 6 Hz in salt water in a machine assembled in the laboratory to provide the slower cycling rate. Figure 4-1 shows a close-up of the tension-tension fatigue test setup in the SF-10 machine. The non-exposed tension-tension specimens developed an endurance limit of 15,000 psi based on gross area stress. The specimens exposed to salt water for 90 days and tested in salt water developed an endurance limit of 20,000 psi. This data showed there was no loss in strength due to the salt water

exposure. A summary of the tension-tension fatigue data is shown in Figure 4-2. Figure 4-3 shows a typical failed specimen tested in tension fatigue.

Exposed and unexposed specimens with holes (.31 inch diameter) were also tested in tension-tension fatigue to provide a test with a greater degree of sensitivity. A summary of this test data is shown in Figure 4-4. As shown, the salt water exposure had no effect on the fatigue life of the composite speicimens in these tests.

Specimens were tested in compression-compression fatigue using a stress ratio of R = 20. They were also tested with and without holes and in the as-fabricated condition and after exposure to salt water. During the tests the specimens were stabilized with steel plates lined with teflon. A summary of the compression-compression fatigue data is shown in Figure 4-5. Both the exposed and non-exposed specimens showed the same trends. The endurance limits attained by both sets were approximately 34,000 psi. There was no deterioration in strength indicated by the specimens exposed to salt water. Similar specimens were tested with a 0.31 inch diameter hole in the test section. These also showed there was no deterioration in strength due to salt water exposure.

In general, the compression fatigue strengths were higher than the tension fatigue strengths. The endurance limit achieved in compression was approximately 34,000 psi compared to 15,000 psi in tension. The increased capability in compression fatigue is attributed (1) to the ability of the titanium cladding to stabilize the outer surfaces, and (2) the elimination of the criticality of micro-cracks normally associated with tension fatigue. As expected, specimens cycled with a complete reversal loading (R = -1) showed the worst fatigue capacility. Table 4-2 summarizes the results attained with specimens cycled at a maximum stress of 25,000 psi. In tension the specimen failed after 72,000 cycles, and in compression the specimen was not failed after terminating the test at greater than 2×10^6 cycles. A third specimen was cycled in tension-compression (R = -1) at a maximum stress of ±25,000 psi. The specimen failed after 10,000 cycles, indicating

the deleterious cumulative effect of the reversal loadings.

Specimens were tested in shear fatigue using rail shear specimens. Rails were bolted to the sides of the specimens and then loaded in a compression mode in a SF-10 fatigue machine. Figure 4-6 shows a close-up of the test setup. Specimens were tested in fatigue to the maximum capability of the test machine, using a 2 to 1 multiplier without failure. At the maximum load, the stress developed was 26,000 psi. Similar tests were performed on a specimen with a .31 inch diameter hole in the test section. One of these specimens cyclic loaded to a shear stress of 22,000 psi failed at approximately 12 x 10^6 cycles. Specimens exposed to salt water for 90 days and fatigued in salt water developed the same fatigue capabilities and showed no deterioration due to the salt water exposure. Table 4-3 summarizes the rail shear fatigue data.

In addition to the previous tests, several beam specimens were tested. They were placed in an environmental chamber at 100 percent salt water humidity and 120°F under 50 percent ultimate load. After various periods of exposure they were removed and tested to failure in bending. The specimens were 10 inches long, 1 inch wide and .35 inch thick. They incorporated 24 plies of T300/934 graphite fabric oriented at (0°, 90°) and had 10 mils of titanium bonded on their upper and lower surfaces. During exposure, loads were applied in 3 point bending in a fixture as shown in Figure 4-7. Specimens were removed at 45 day intervals up to a total of 10½ months and tested to failure. None of the specimens showed any loss in strength. A summary of this test data is shown in Table 4-4.

The results from the materials environmental exposure studies showed that the titanium clad graphite/epoxy material system is suitable for hydrofoil boat applications. The in-plane strength and fatigue characteristics did not deteriorate after 90 days of submergence in salt water. The bending strength characteristics of the composites did not deteriorate after carrying a sustained 50 percent ultimate load in a 100 percent salt vapor and 120°F environment for periods up to 10½ months.

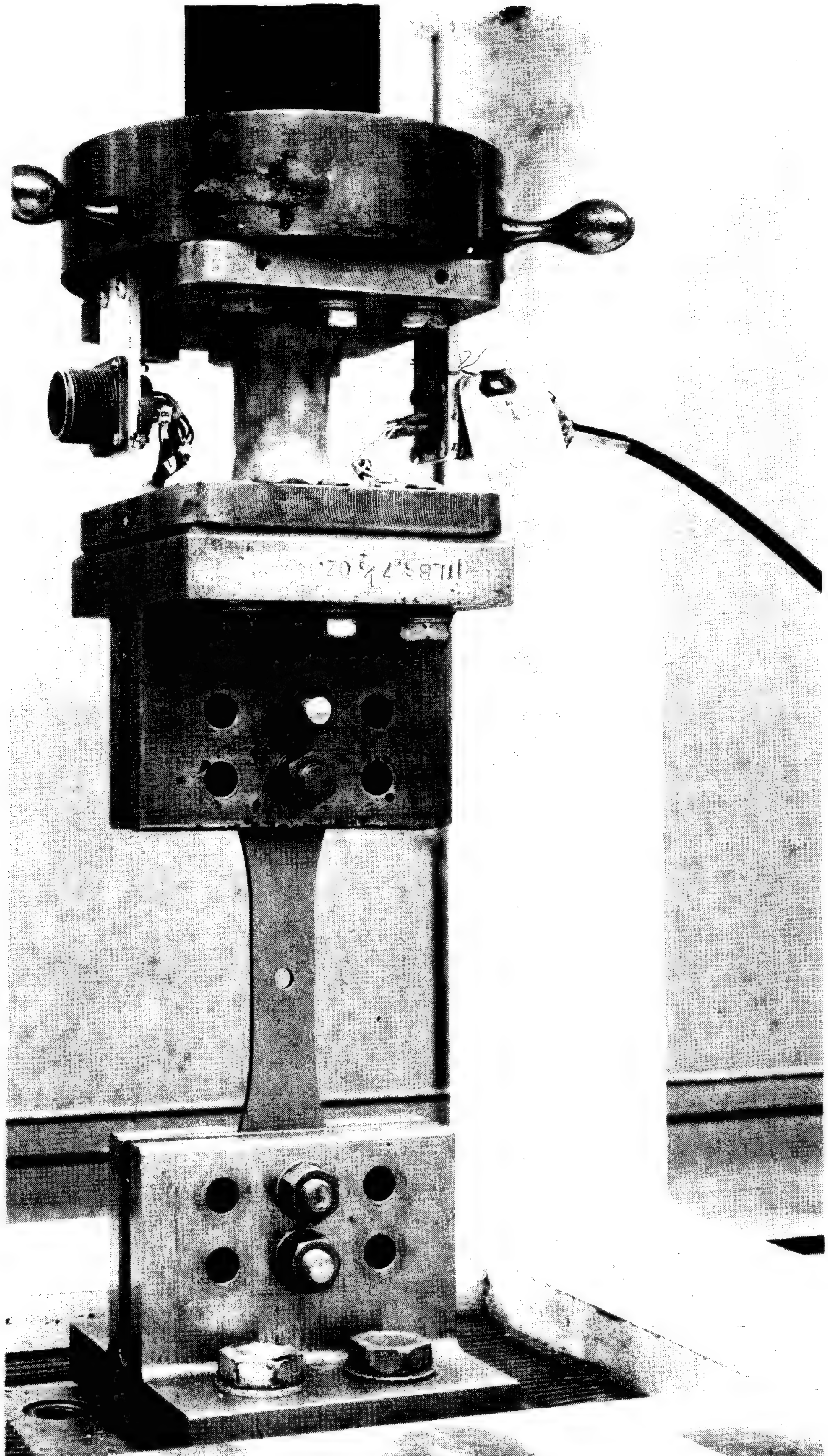


FIGURE 4-1 TENSION-TENSION FATIGUE TEST SETUP

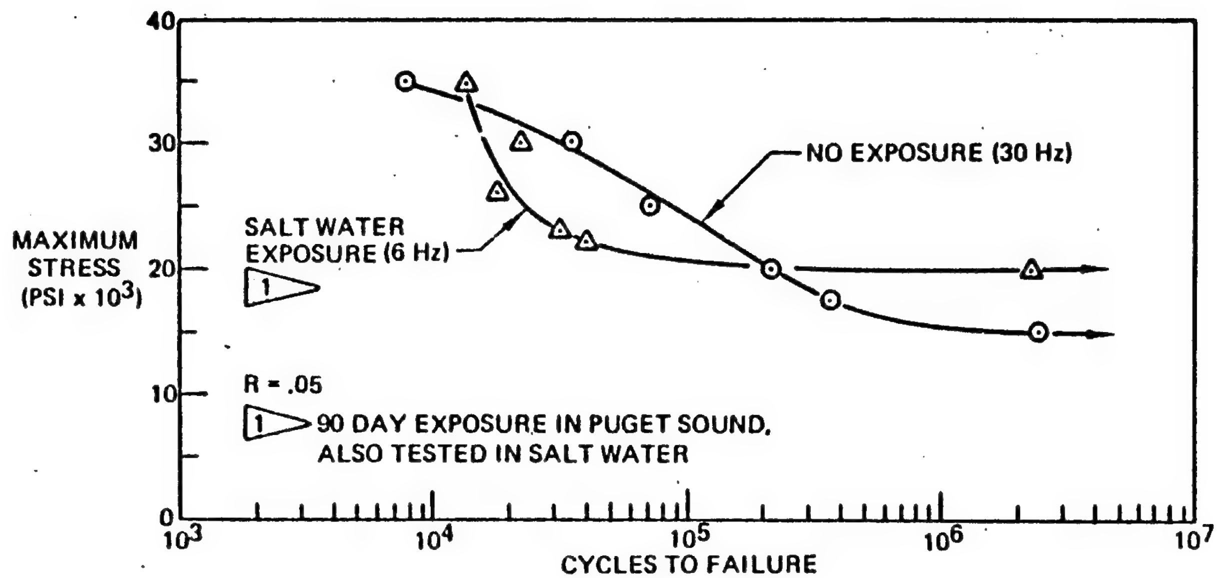


FIGURE 4-2 TENSION-TENSION FATIGUE PROPERTIES (NO HOLE)

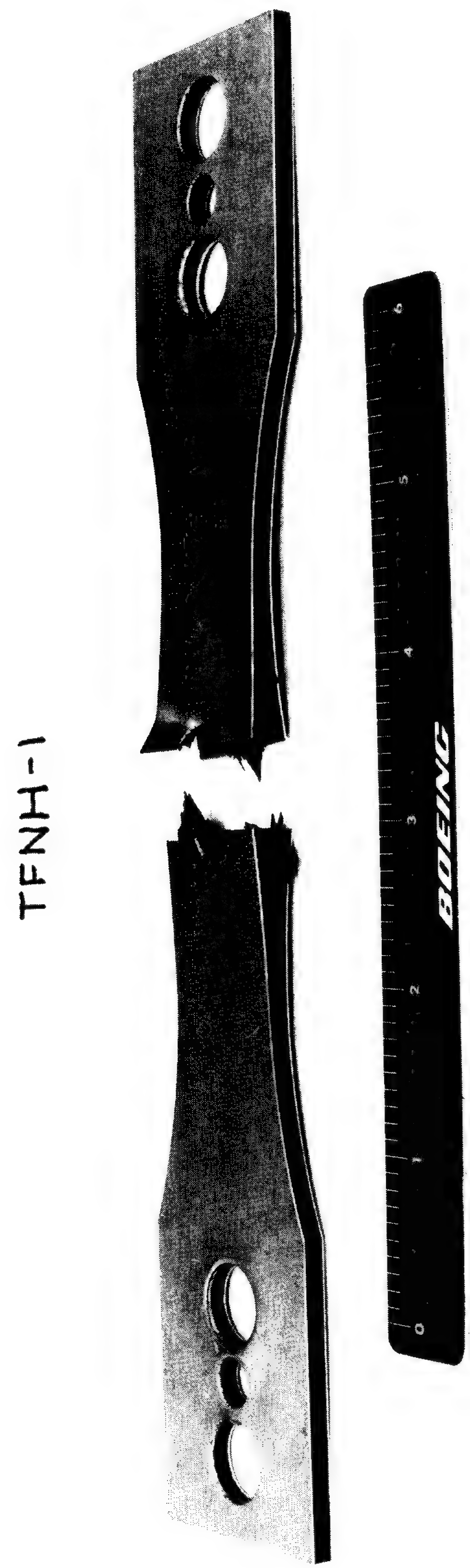


FIGURE 4-3 TENSION FATIGUE FAILED SPECIMEN

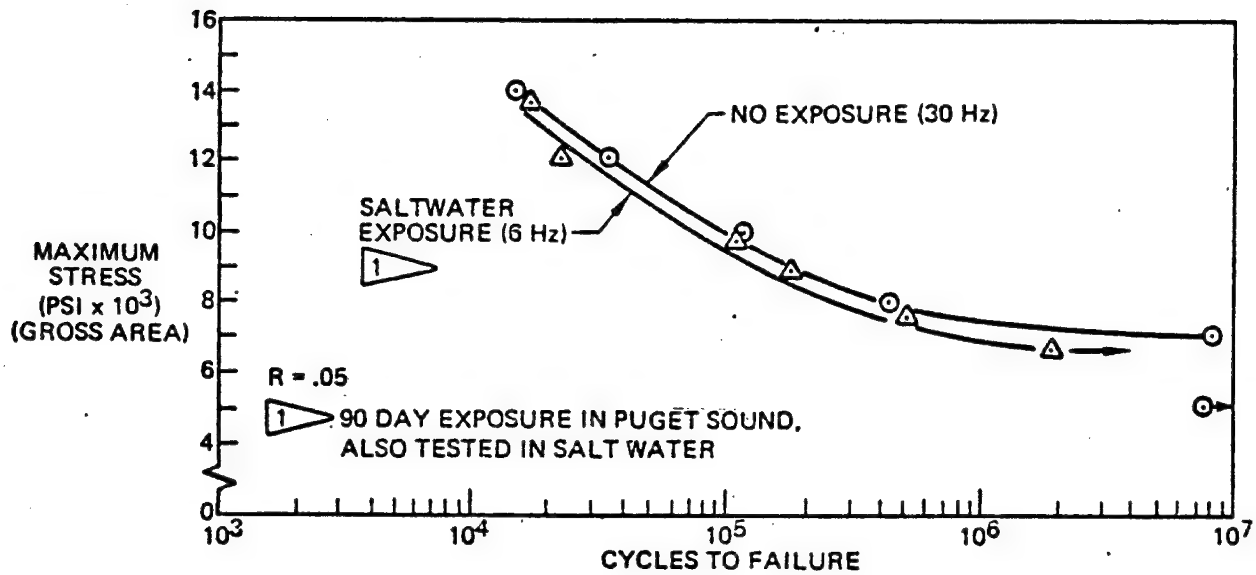


FIGURE 4-4 TENSION-TENSION FATIGUE PROPERTIES (0.31 INCH DIAMETER HOLE)

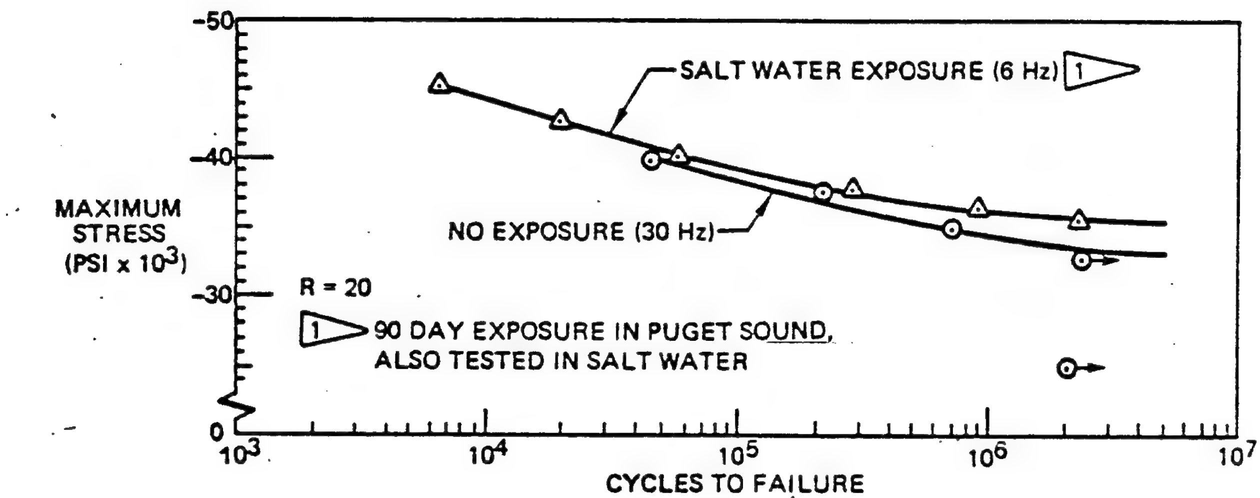


FIGURE 4-5 COMPRESSION-COMPRESSION FATIGUE PROPERTIES (NO HOLE)

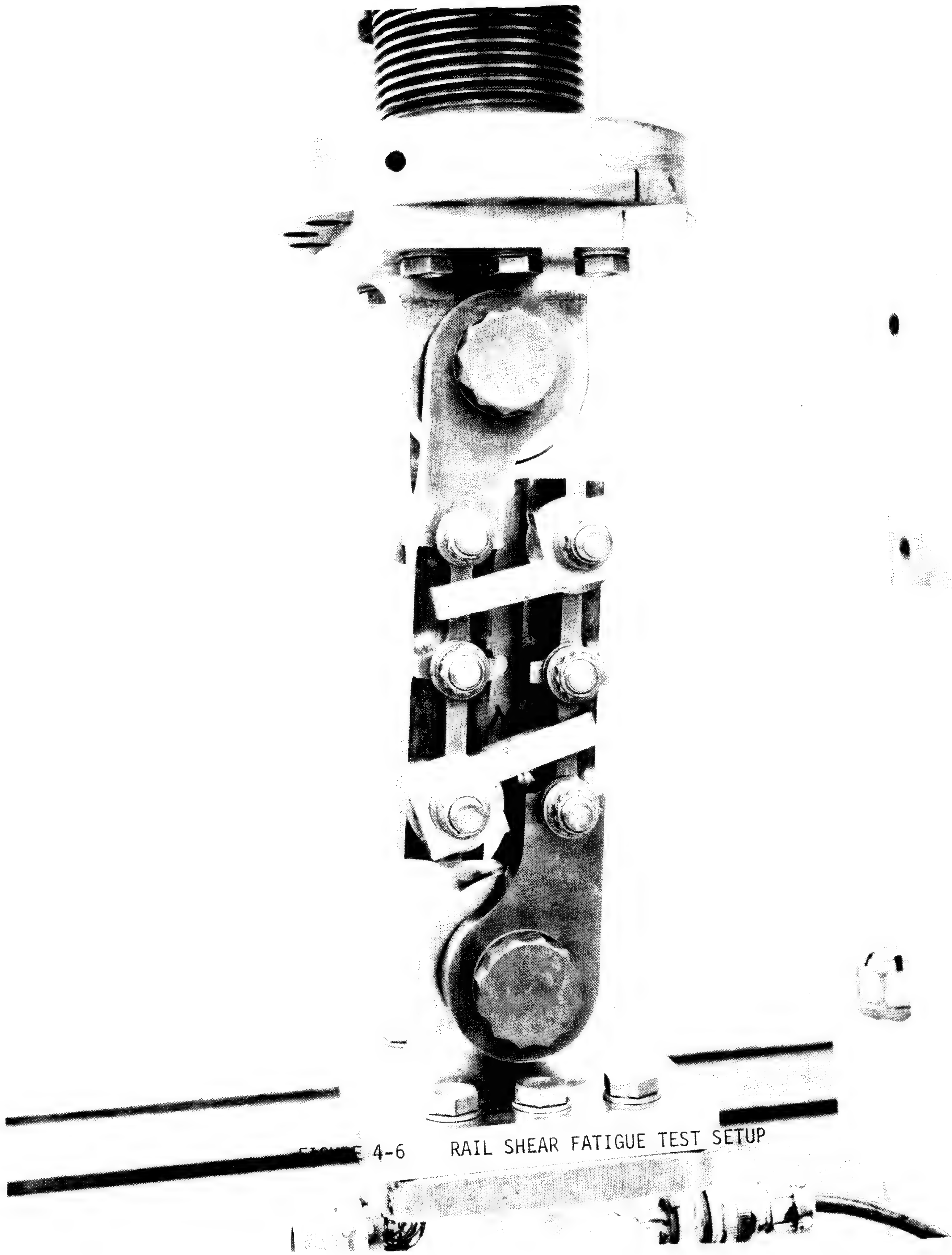


FIGURE 4-6 RAIL SHEAR FATIGUE TEST SETUP

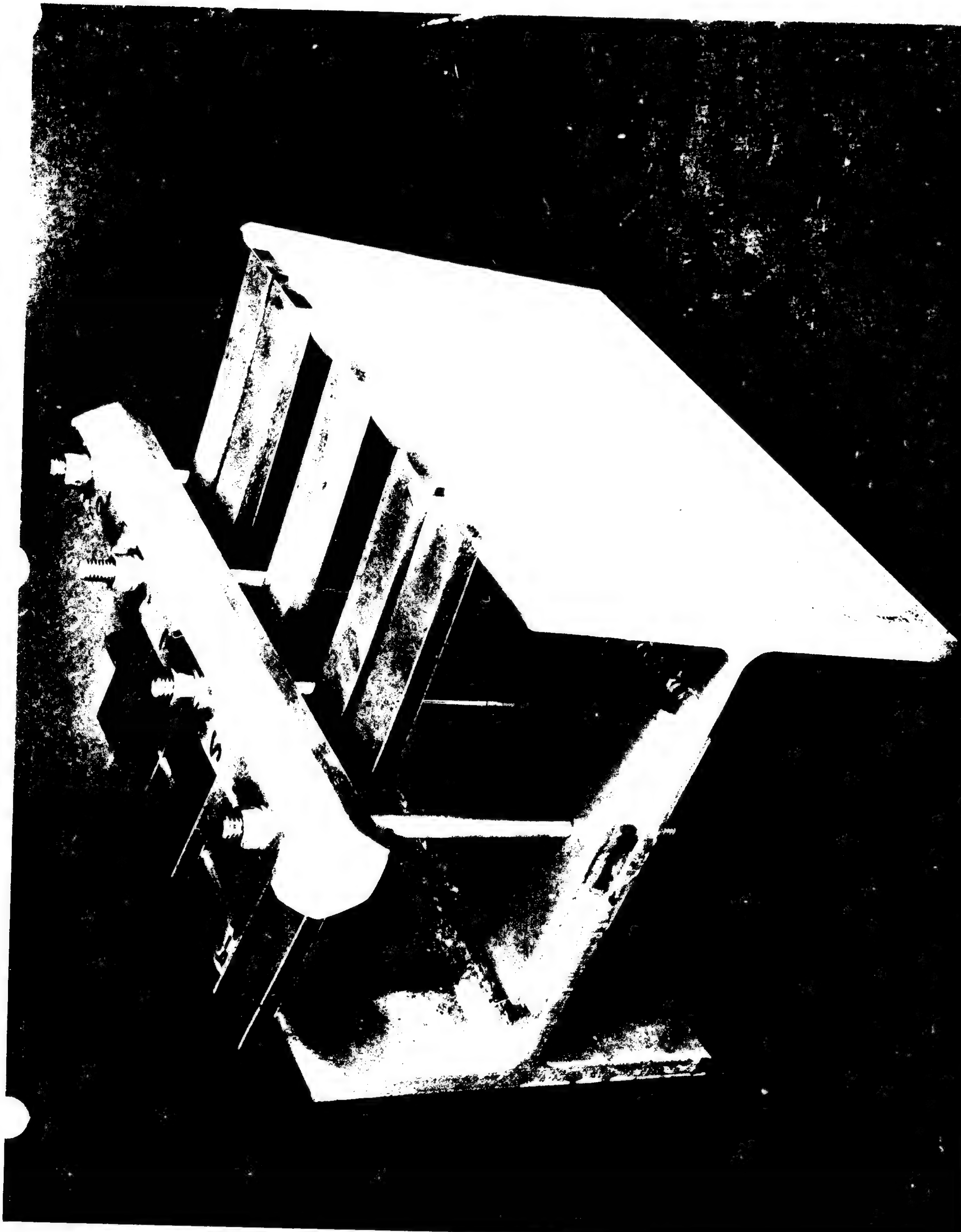


FIGURE 4-7 GRAPHITE/EPOXY BEND SPECIMEN IN PRELOAD FIXTURE

TABLE 4-1

STATIC PROPERTIES GRAPHITE FABRIC/EPOXY-TITANIUM CLAD PLATE

	AS FABRICATED				90 DAY SALT WATER EXPOSURE(2)			
	STRENGTH, PSI (1)		E	G	STRENGTH, PSI (1)		E	G
	YIELD	ULTIMATE			YIELD	ULTIMATE		
TENSION	37,700	45,900	4.6	–	37,700	45,900	4.6	–
COMPRESSION	44,500	–	5.2	–	42,600	–	4.8	–
RAIL SHEAR	–	40,200(3)	–	4.6	–	35,400	–	4.5
INTERLAMINAR SHEAR	10,300	–	–	–	11,100	–	–	–
FRACTURE(4)	–	41,300	–	–	–	41,500	–	–

(1) BASED ON GROSS AREA (COMPOSITE, BONDLINE, CLADDING)

(2) IMMERSED IN PUGET SOUND

(3) ALL FAILURES THRU GRIPS

(4) FLAW SIZE:

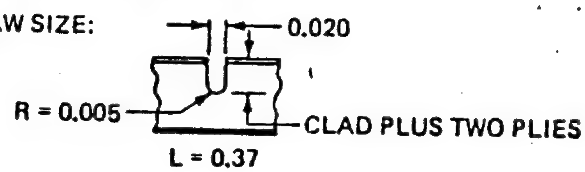


TABLE 4-2

FATIGUE AT 25,000 PSI (MAXIMUM)

TYPE LOADING	STRESS RATIO (R)	MAXIMUM STRESS (PSI)	NUMBER OF CYCLES
TENSION–TENSION	0.05	25,000	72,000
COMPRESSION–COMPRESSION	20.0	-25,000	N.F.
TENSION–COMPRESSION	-1	±25,000	10,000

TABLE 4-3

RAIL SHEAR FATIGUE DATA

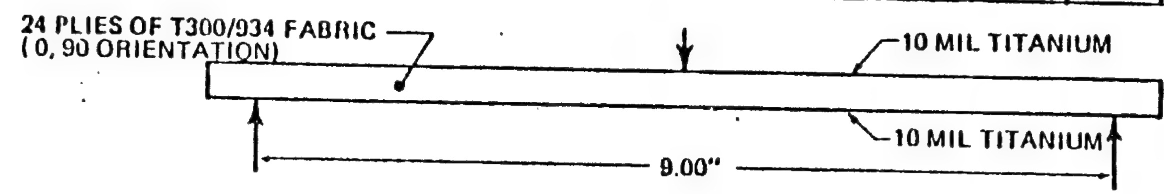
	MAXIMUM STRESS, PSI (GROSS AREA)	NUMBER OF CYCLES
STATIC	40,200	–
RAIL SHEAR (NO HOLE)	15,000 26,600 (1) 20,700(3)	N.F. 3,468,000 (2) 1,553,000
RAIL SHEAR (WITH HOLE)	25,000 22,000	783,000 11,980,000

(1) MAXIMUM MACHINE CAPACITY
(2) Ti CLADDING FAILED AFTER APPROX. 2 MILLION CYCLES
(3) FATIGUE TESTED IN SALT WATER AFTER 90 DAYS EXPOSURE IN PUGET SOUND

TABLE 4-4

FLEXURE STRENGTHS - AFTER STORAGE AT 50 PERCENT ULTIMATE LOAD IN 100 PERCENT SALT WATER VAPOR AT 120°F

SPECIMEN TYPE	TYPE OF EXPOSURE	DAYS EXPOSURE							
		0	45	90	135	180	225	270	315
10" BEAM SPECIMEN	NONE (CONTROL)	110,770	—	—	—	—	—	—	—
10" BEAM SPECIMEN	UNSTRESSED IN PUGET SOUND	—	104,010	104,000	—	—	—	—	—
10" BEAM SPECIMEN	UNSTRESSED LAB SALT SPRAY	—	105,500	—	—	—	—	—	—
10" BEAM SPECIMEN	50% ULTIMATE LAB SALT SPRAY	—	—	107,080	—	—	—	—	—
10" BEAM SPECIMEN	50% ULTIMATE LAB SALT SPRAY	—	—	—	106,700	124,990	110,700	115,130	108,55



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5.0 FEASIBILITY COMPONENT

A demonstration component representative of the crank-end of the composite flap was fabricated and fatigue tested to develop manufacturing procedures and demonstrate the structural capabilities of the design. This assembly incorporated a titanium crank-spar subassembly and composite covers which extended beyond the first flap bearing (Figure 5-1). This assembly was fatigue tested in salt water and failed prematurely. The component was repaired and reinforced in the failed area. It failed prematurely during a second fatigue test. As a result of these failures, changes were incorporated in the full-scale composite flap which emphasized improved fatigue life characteristics.

5.1 FEASIBILITY COMPONENT DESIGN AND ANALYSIS

A composite demonstration component design was developed which was based on the preliminary full-scale composite flap design shown in Figure 5-2. The component design simulated the outboard crank-end of the flap. It extended inboard to include the first flap bearing.

The demonstration component incorporated a titanium crank and spar. The crank angular off-sets required for proper ship installation were not used to simplify machining. The spar cross-section consisted of an "I" configutation with tapered flanges. The spar and crank were assembled by electron beam welding.

The upper and lower covers were 22 inches long. They incorporated 36 plies of fabric (T300/934) oriented at ±45 degrees. The surfaces of the composite covers were clad with 10 mils of 6Al-4V titanium.

The covers and the titanium crank-spar substructure were assembled by both bonding and mechanical attachments. The adhesive cure cycle was performed at 250°F temperature in an autoclave at 50 psi. Mechanical blind fasteners were incorporated as a second load transfer path in the nose and closure

rib area.

Both a hand analysis and a NASTRAN model were used in the analysis of the preliminary design of the full-scale flap. The feasibility component was designed to be representative of this same configuration and, therefore, the same analysis applied. This work was reported in Section 3.0.

5.2 FEASIBILITY COMPONENT FABRICATION

The feasibility component incorporated the same materials and used the same processing and manufacturing techniques proposed for the full-scale flap to evaluate the associated fabrication procedures. The titanium crank and spar were initially rough machined and then electron beam welded into a single assembly (Figure 5-3). This assembly was then finish machined to its final configuration.

The composite covers were laid up on an egg-crate stabilized steel tool. The tool surface was swept with a tool compound to correct for welding distortions and to bring the surface within contour tolerances. Figure 5-4 shows one of the covers being laid up in the tool and the trailing edge doubler that was incorporated. The lay-up was vacuum bagged and cured in an autoclave at 350°F and 50 psi. The covers were trimmed in a milling machine and 10 mil titanium cladding was then secondarily bonded on their surfaces with Hysol EA9628 adhesive.

After all of the detail parts were completed, the parts were pre-assembled. A foamed adhesive was placed at all the bonding interfaces. This assembly was bagged and autoclave cured. The component was then disassembled and the foamed adhesive thickness measured to determine the number of adhesive layers required at various locations. During pre-assembly the attachment holes were also drilled. Figure 5-5 shows all the details prior to final assembly. The details were then assembled with adhesive in place, bagged, and cured in an autoclave. Figure 5-6 shows the completed assembly.

5.3 FEASIBILITY COMPONENT TEST

The component was bolted to a steel base plate and placed in a clear lucite tank. The base plate was bolted to the bottom of the tank which was then filled with salt water. A 30 kip jack was attached to the titanium crank. A controller was used to repeat the load spectrum representative of hydrofoil service conditions shown in Figure 5-7. The overall test setup is shown in Figure 5-8.

Shortly after the cyclic loading was initiated, differential movements were noted between the covers and the substructure in the closure rib, nose plate, and hinge cut-out areas. Afterseveral thousand additional loadings, several of the mechanical attachments loosened and finally one failed in the closure rib area. The loadings continued until the component failed after approximately 12,000 cycles. This occurred far short of the 16 x 10^6 cycles required to demonstrate a safe life compliance.

The primary failure consisted of the fracture of the titanium closure rib. It was preceded by a bond failure along the nose of the flap which drastically changed the load paths to the composite covers. The resulting loads produced high bending stresses in the closure rib causing it to fail. Subsequent analysis and examination of the detail parts strongly backed this sequence of failure events.

A finite element model of the flap was used to analyze the flap under the fatigue test conditions. Analyses were performed with and without bonds in the nose area of the flap to determine the degree that the stresses increased due to the resulting load path change. When bond failure was assumed, the bending stresses increased drastically to 67 ksi in the area of the failure. At this stress level in the presence of bolt holes, titanium parts have a very limited fatigue life.

The failed flap was disassembled and the detail parts examined. The composite covers were in excellent shape. The majority of the bond area

between the covers and the titanium spar and crank assembly had to be pried apart with a screwdriver, indicating very good adherence. The area in the nose of the flap showed some voids and a lack of bond. It was theorized that threaded attachments installed prior to the cure cycle caused the covers to hang-up and prevented positive pressure in these areas. The failure in the titanium closure rib did not extend through its full depth. It occurred on the tension side of the rib through a bolt hole, as shown in Figure 5-9.

5.4 FEASIBILITY COMPONENT REDESIGN

Several design changes were incorporated in the feasibility component as a result of its premature failure during the initial fatigue test. A 2½ inch thick reinforcement was welded to the closure rib. In the nose area the splice plate was increased in thickness, a third row of rivets were added and all the rivets were increased in diameter. The flange of the nose rib adjacent to the hinge cut-out was increased in width to accept a larger number of rivets. The diameter of the rivets through the trailing edge were increased to ¼ inch diameter. Additional rivets were added in the forward portion of the crank. The majority of these changes are shown in Figure 5-10.

A NASTRAN analysis was performed using a finite element model which incorporated the above changes. The results showed that torsion loads transferred to the covers from the crank could be carried by either the bond or the mechanical attachments. Also, if a debond did occur similar to the failure experienced in the first test the rib reinforcement would reduce the bending stresses sufficiently to permit the rib to carry the remainder of the cyclic loads.

5.5 FEASIBILITY COMPONENT REBUILD

The feasibility component was rebuilt for further test evaluation. During rebuilding, several design and process changes were incorporated. The closure rib was repaired by hand welding. A 2½ inch thick reinforcement

bar was welded to its outer surface as shown in Figure 5-11. A flange extension was also welded on the nose rib and can also be seen in this figure.

During the disassembly of the component a small area of the surface cladding was debonded. During the subsequent removal of the cladding some of the surface plies were damaged. The plies were trimmed and stepped as shown in Figure 5-12, and a patch fitted and bonded to repair the damage.

During the assembly of the covers and titanium substructure, several procedural changes were used to permit the full 100 psi autoclave pressure to be used during the bond cycle. The details were first cleaned and primed and assembled with adhesive in place. The interior of the flap was then filled with 1/8 inch diameter spherical aluminum balls and a ¼ inch thick blanket of neoprene rubber was placed along the inner surface of one of the covers. The interior of the assembly was then sealed with a metal end plate and the overall assembly was then bagged in a conventional manner. It was then processed through an adhesive cure cycle in an autoclave at 250°F and 100 psi. After the cure was completed and the bagging material removed, the part was examined and adhesive flow was observed at all edges of the interfacing surfaces, which indicated an excellent bond had been achieved.

The flap assembly was then cleaned. Holes were drilled and the fasteners installed to complete the assembly. Figure 5-13 shows the completed rebuilt assembly.

5.6 FEASIBILITY COMPONENT RETEST

The rebuilt component was set up for a fatigue test as described in Section 5.3 and as shown in Figure 5-8. Loads were applied at a cyclic rate of 3 Hz at the levels shown in Figure 5-7. The part failed after 145,000 cycles. The failure occurred in the forward cell of the titanium closure rib near the base of the shaft as shown in Figure 5-14. The crack passed through the termination of the weld used to install the closure rib

reinforcement which was considered the initiation point of the failure.

5.7 FEASIBILITY COMPONENT - CONCLUSIONS

The composite flap design incorporated ½ inch thick laminates which presented unique design and fabrication considerations. The feasibility component incorporated these details and its evaluation provided data that was used to improve the producibility and performance of the full-scale composite flap.

Several fabrication techniques were evaluated during the assembly of the feasibility component and the most promising were selected for assembly of the full-scale composite flap. The fit-up between the covers and the titanium substructure was determined by the use of encapsulated foamed adhesive. The flap was pre-assembled with the adhesive in place between layers of IEP parting film. This assembly was placed in an oven and processed through the adhesive cure. The flap was then disassembled and the thicknesses of the foamed adhesive measured. These measurements were used to determine the number of layers of film adhesive to be used at specific locations.

All blind fasteners were removed from the flap design due to their poor fatigue performance during test of the feasibility component. All fasteners were changed to 6Al-4V titanium and were either through-bolts or bolts torqued into internal nut plates.

The titanium crank-spar details proved to be the most critical structure of the feasibility assembly. To improve their capability, several of the transition areas were changed and all holes and metal surfaces were shot peened.

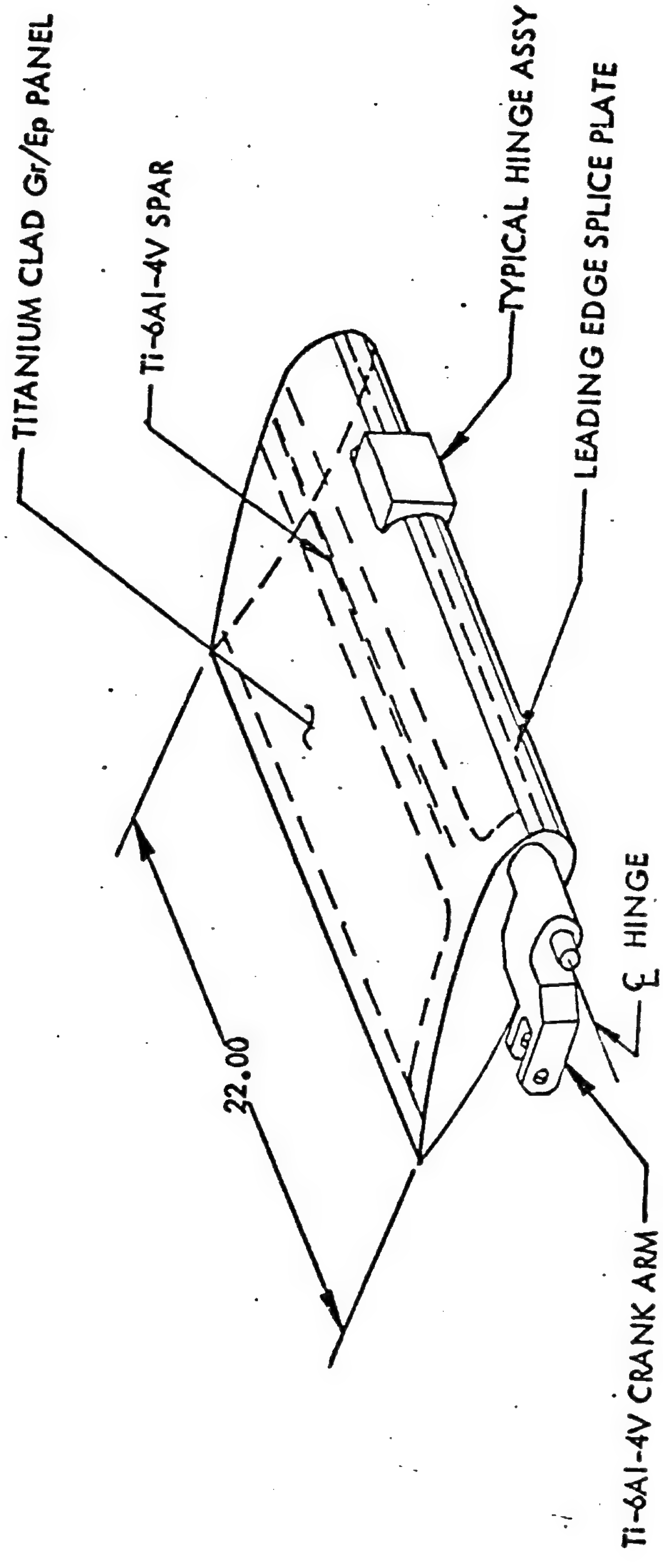


FIGURE 5-1 FLAP FEASIBILITY COMPONENT - SKETCH

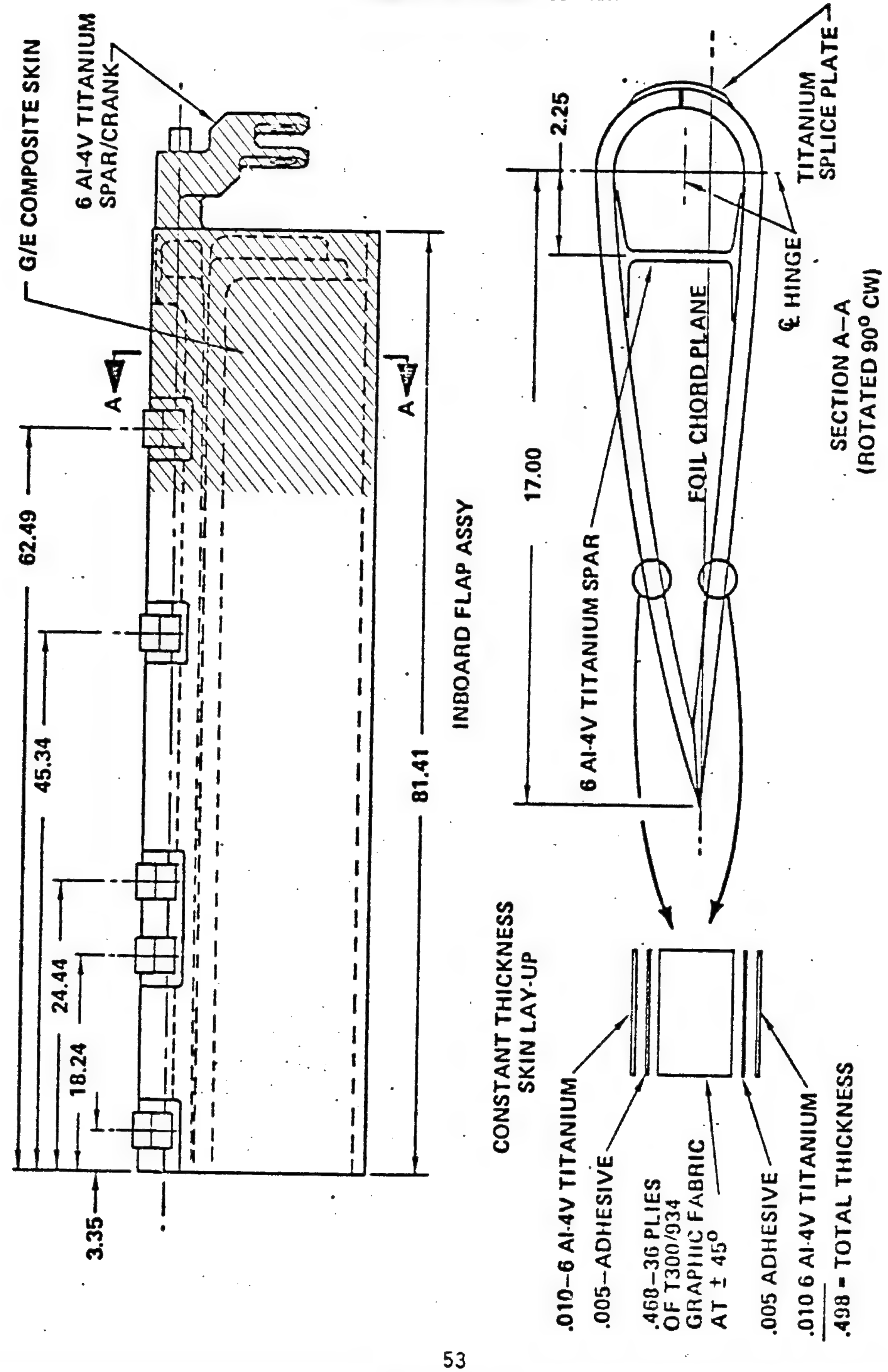
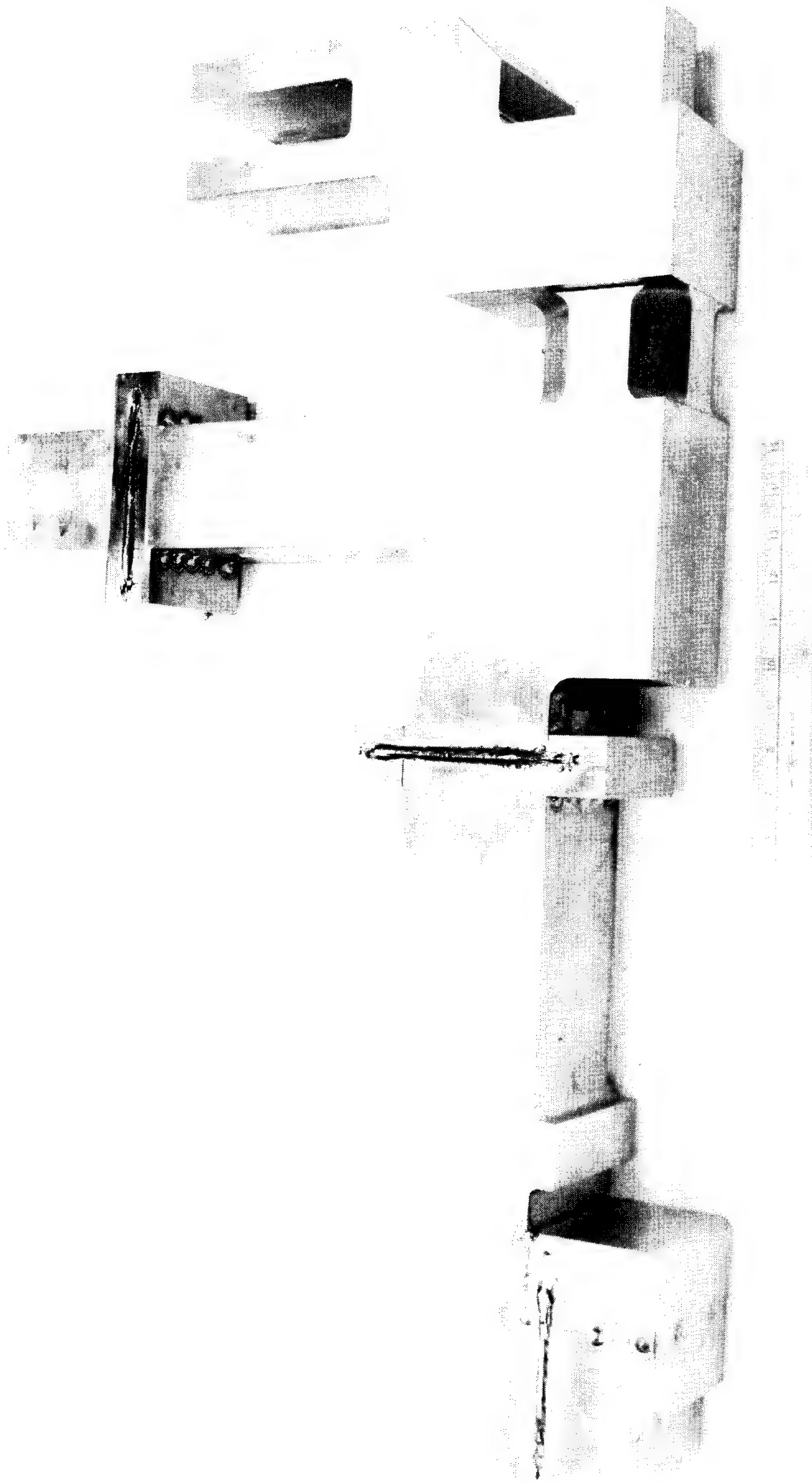


FIGURE 5-2 FLAP PRELIMINARY DESIGN FEASIBILITY COMPONENT



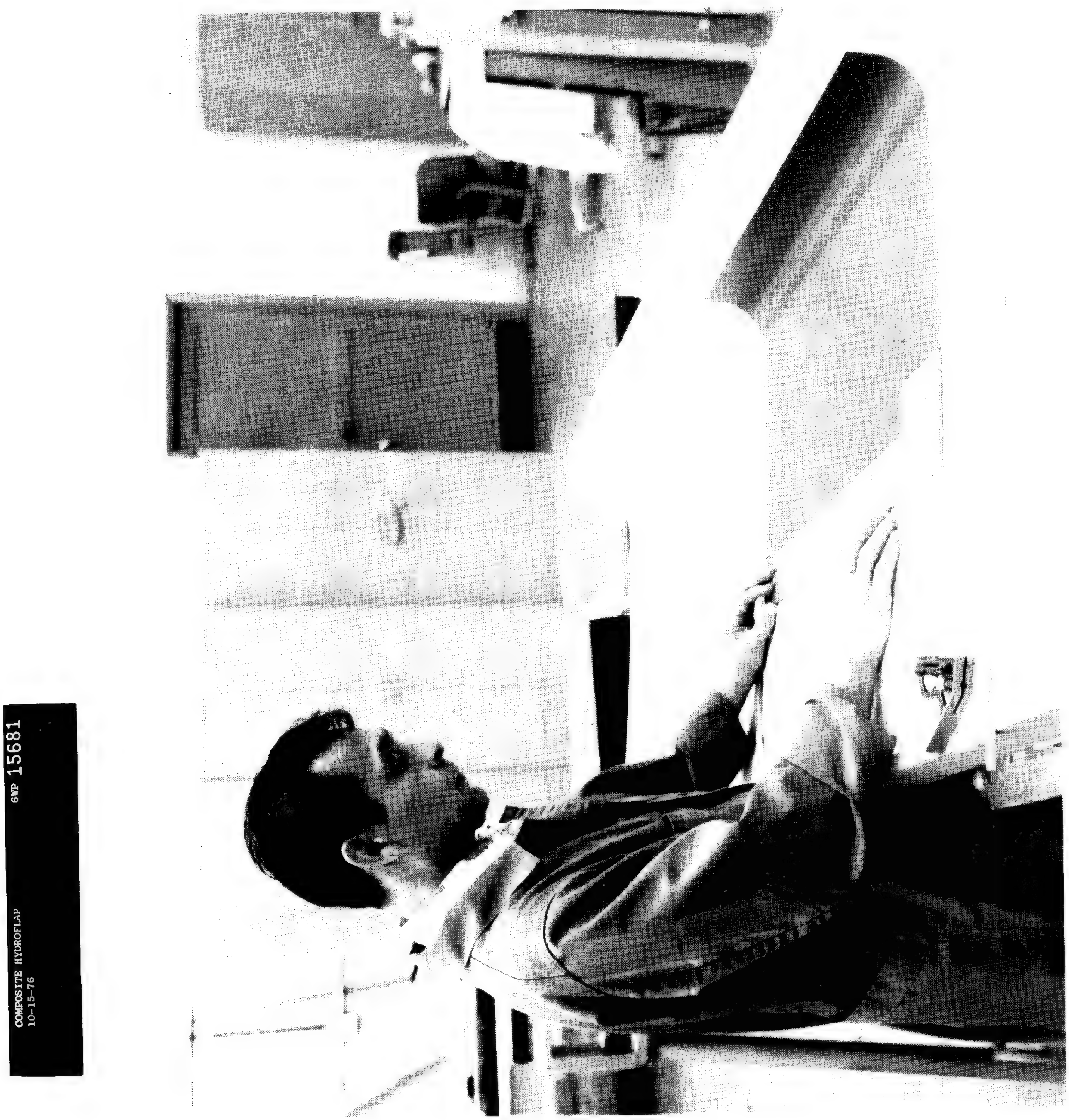


FIGURE 5-4 COMPOSITE COVER LAYUP

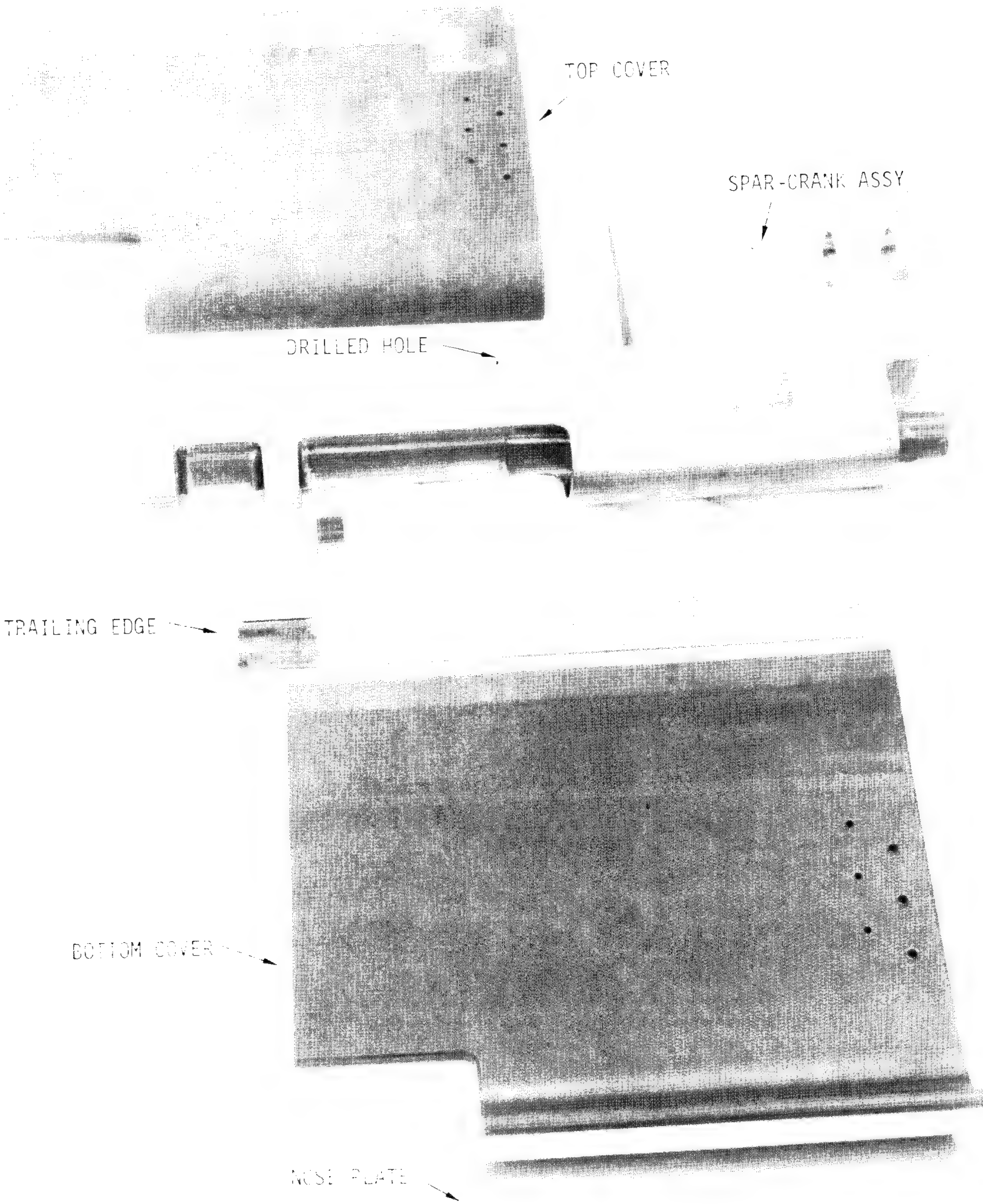


FIGURE 5-6 FEASIBILITY COMPONENT - DETAILS

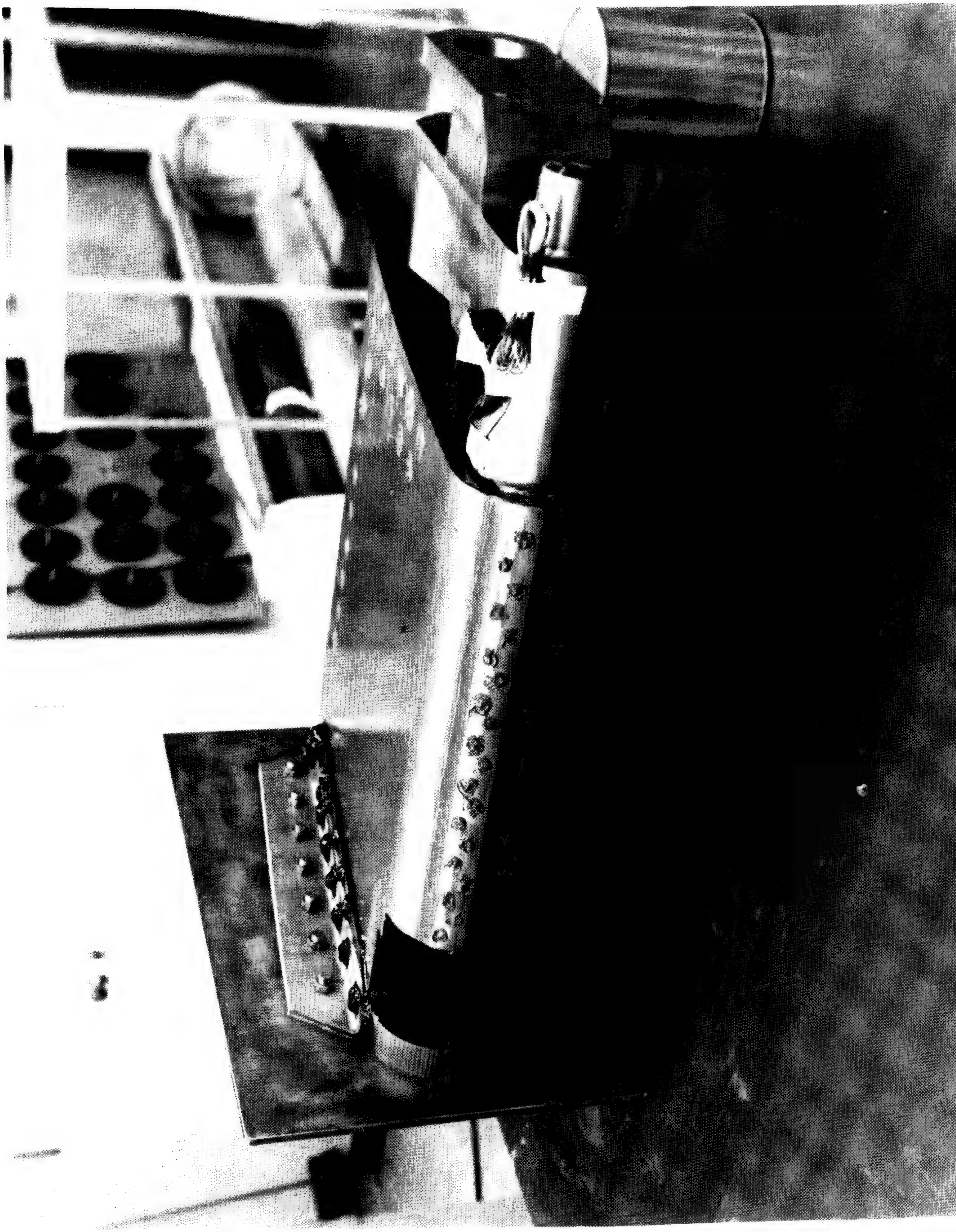


FIGURE 5-6 FEASIBILITY COMPONENT ASSEMBLY

- IN SALT WATER
- BASED ON ULTIMATE LOAD = 467.5 INCH KIPS (6300 PSF)
- CYCLIC BLOCK = 1000 CYCLES *
  - 544 CYCLES AT 30 PERCENT
  - 312 CYCLES AT 35 PERCENT
  - 138 CYCLES AT 40 PERCENT WITH EVERY 20TH CYCLE A 20 PERCENT REVERSAL LOAD
- CYCLIC RATE = 3 HERTZ

* BASED ON ULTIMATE LOAD = 467.5 INCH KIPS (6300 PSF)

FIGURE 5-7 FEASIBILITY COMPONENT TEST

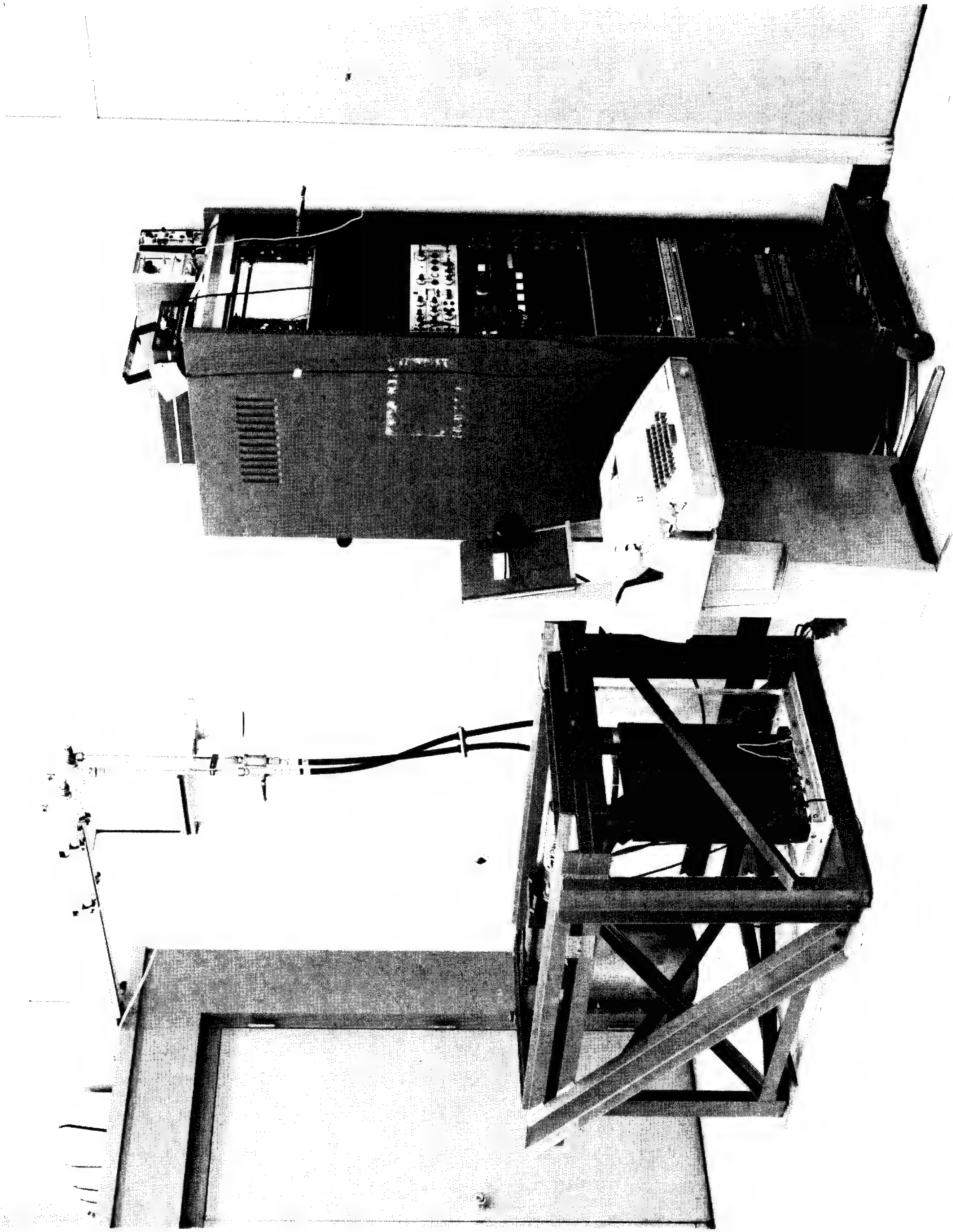


FIGURE 5-[illegible] FEASIBILITY COMPONENT TEST SETUP

FIGURE 5-[illegible] TITANIUM CLOSURE RIB FAILURE

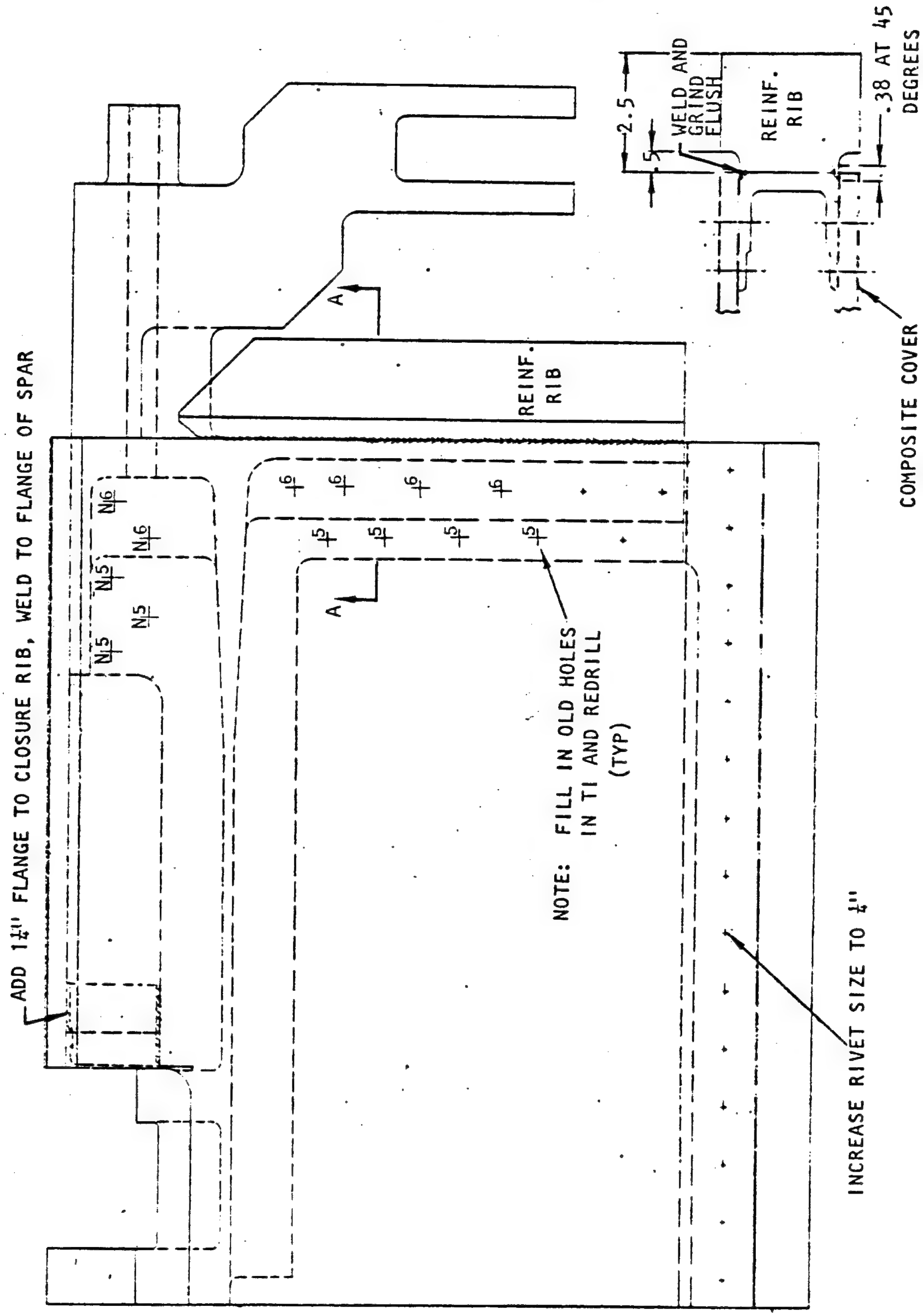
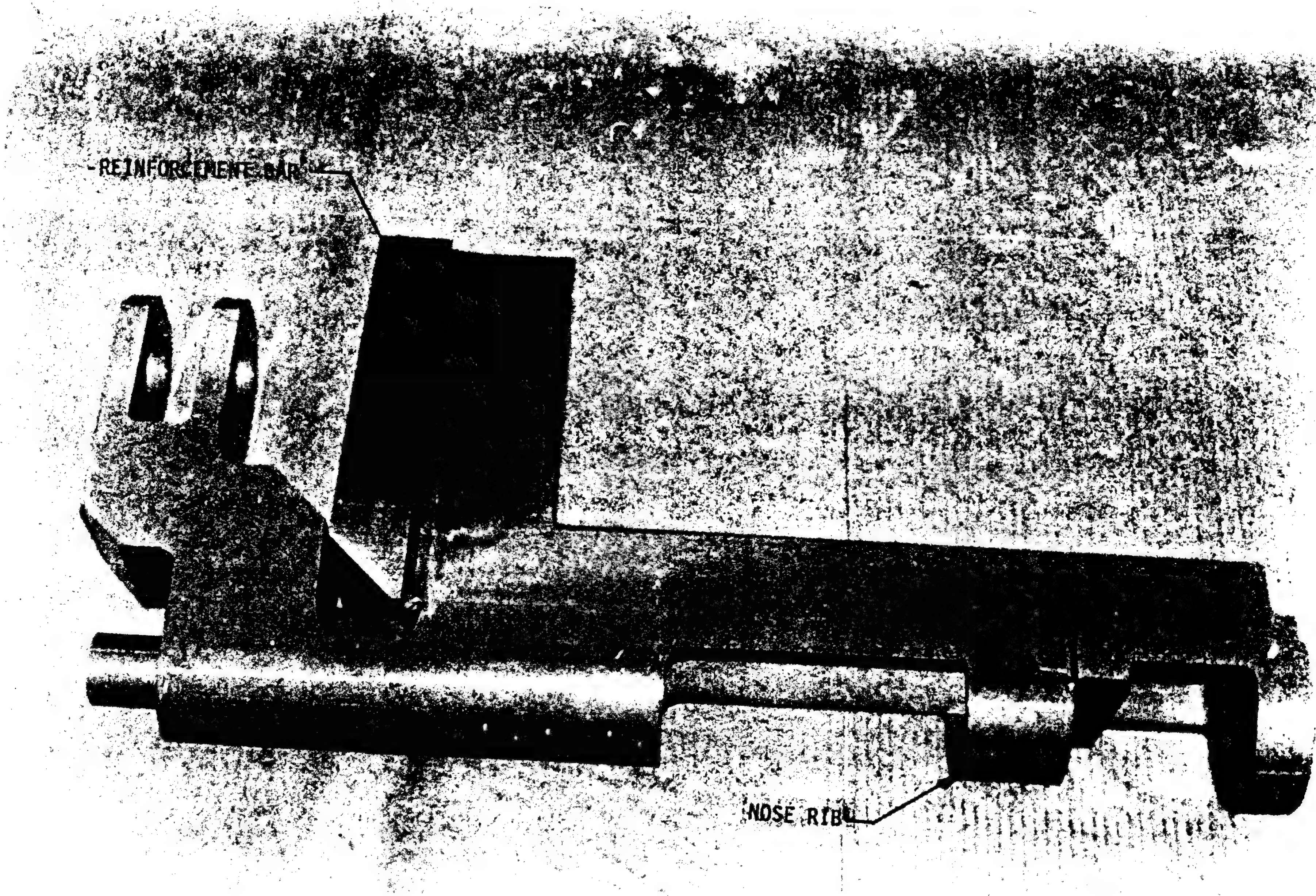


FIGURE 5-10 FEASIBILITY COMPONENT REDESIGN FIGURE



-11 SPAR CRANK ASSEMBLY - [illegible]

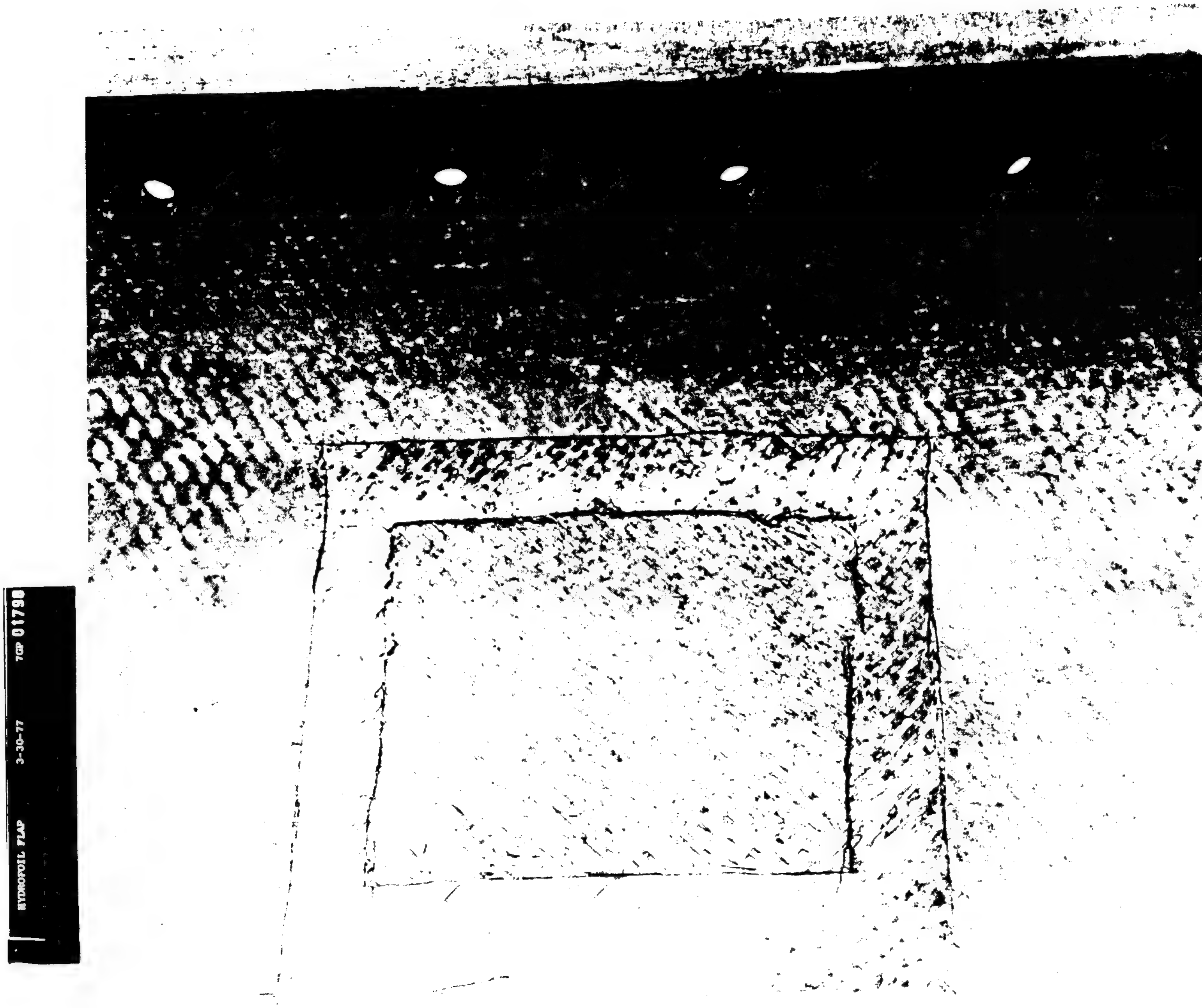
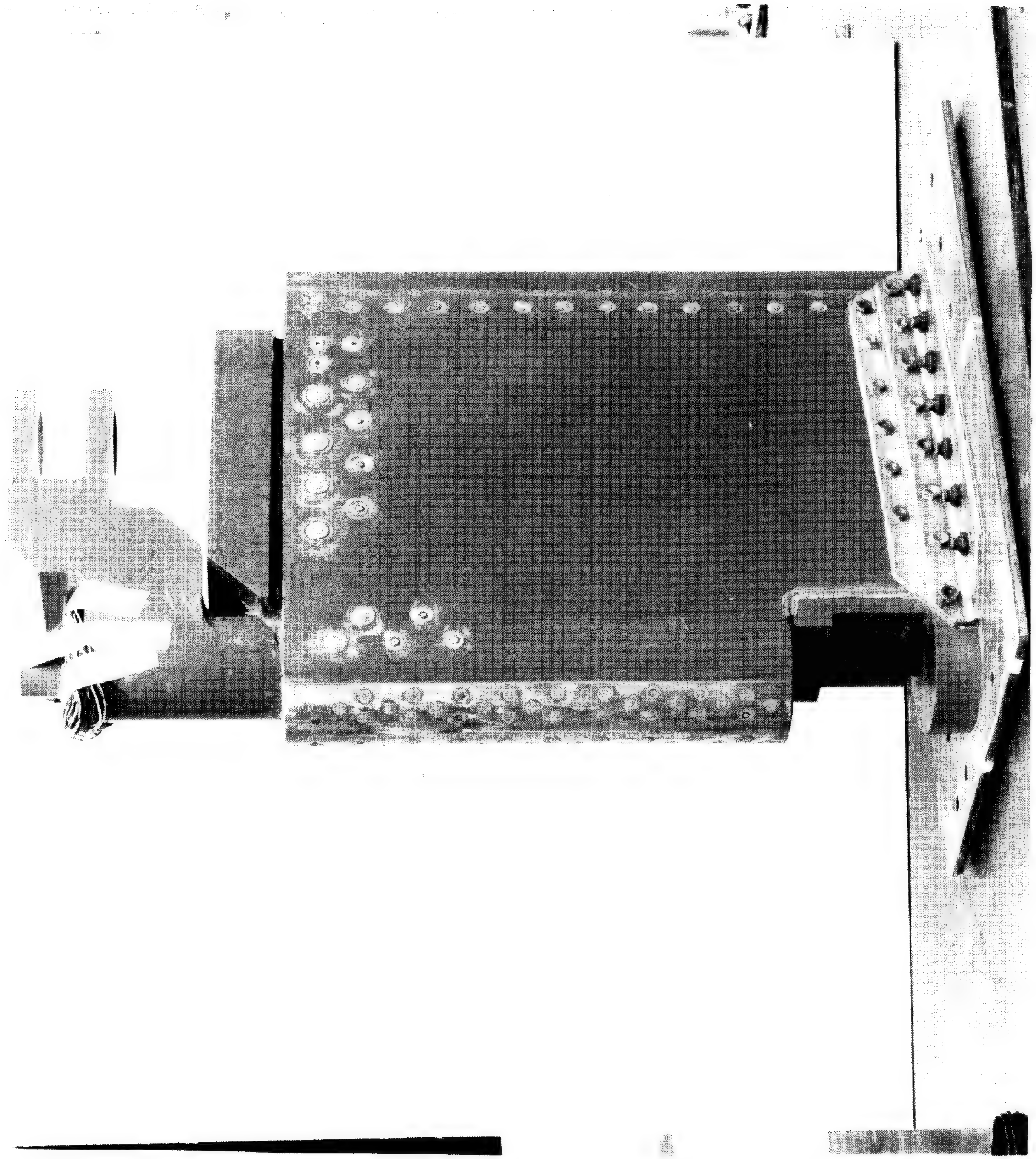


FIGURE 5-1 COMPOSITE COVER REPAIR



TWP 09612
COMPOSITE HYDROFOIL FLAP
6-6-77

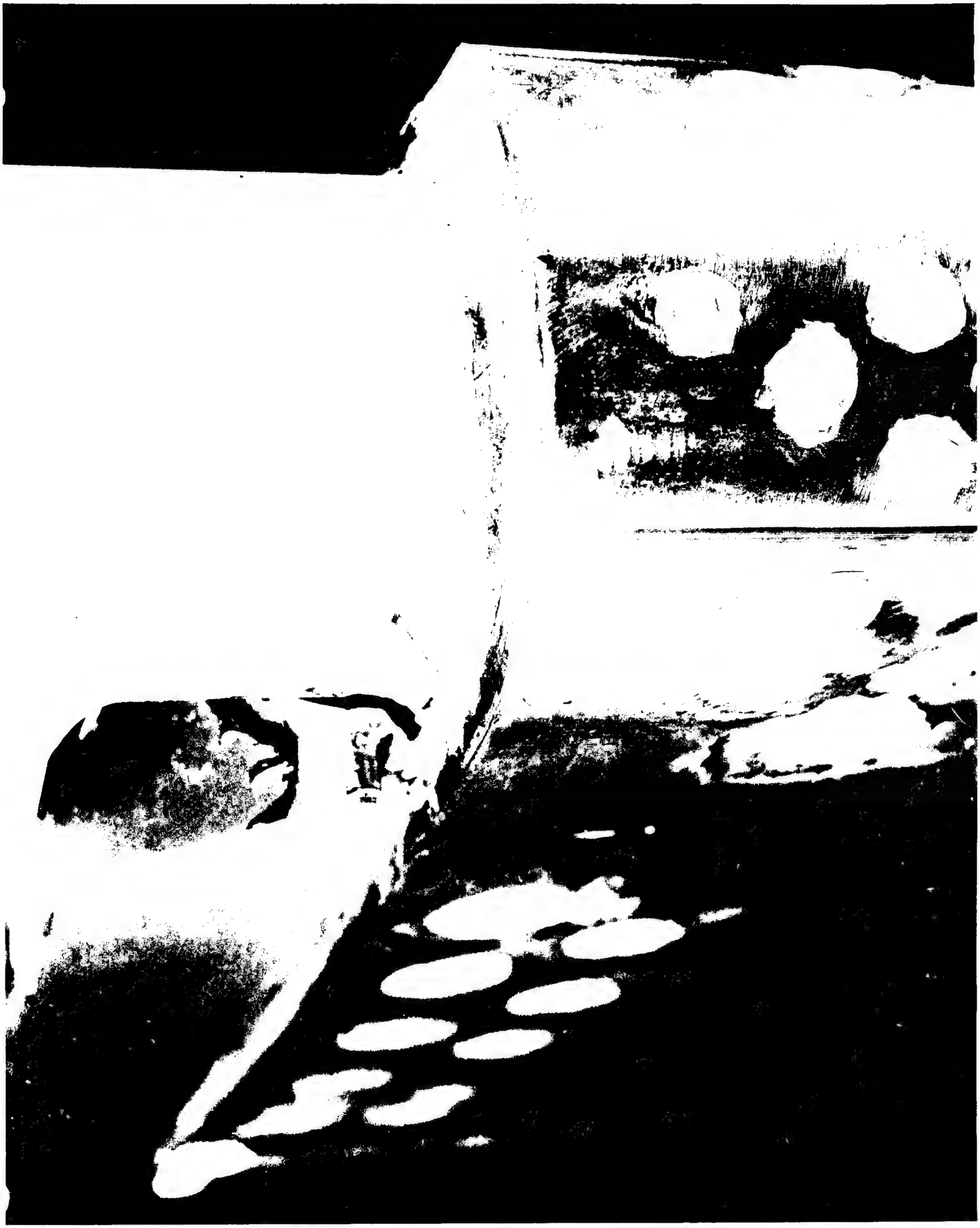


FIGURE 5-14 FEASIBILITY COMPONENT - SHAFT FAILURE

6.0 MECHANICAL ATTACHMENT TESTS

Mechanical fastener joint tests were performed to establish the most promising techniques for installing the thick laminates used in the flap design. Several types of fasteners and inserts were evaluated. Both static and fatigue tests were performed.

The specimens used in this evaluation incorporated ½ inch thick composite laminates attached to a steel fixture with single fasteners. The composite laminate was the same as the design of the composite covers used in the flap. It consisted of 36 plies of graphite/epoxy fabric clad with 10 mils of titanium bonded on their surfaces. The steel was counterbored in the fastener area to the same thickness as the substructure used in the flap design. A sketch of the specimen is shown in Table 6-1.

Three types of concepts used in the laminates around the fasteners to transfer load were evaluated. In one, the basic laminate was used directly in bearing; in a second, a stepped titanium insert was used; and in a third, a titanium doubler was incorporated. Sketches of the three concepts are shown in Figure 6-1.

Three types of fasteners were evaluated. One was a torqued bolt, a second a Huck blind bolt, and a third a Visulock blind bolt. All fasteners were 3/8 inch diameter.

Eight specimens were tested in fatigue. They were subjected to sine wave loading varying between a maximum of 3000 lbs and a minimum of 15 lbs at a frequency of 10 Hz. The maximum load was representative of the fastener load transfer requirements in the composite flap design for service load conditions. The testing was performed in a 60 kip hydrualic fatigue test machine, using a MTS servo controller. A photograph of the test set up is shown in Figure 6-2.

Three specimens with 3/8 inch diameter torqued bolts were tested in fatigue

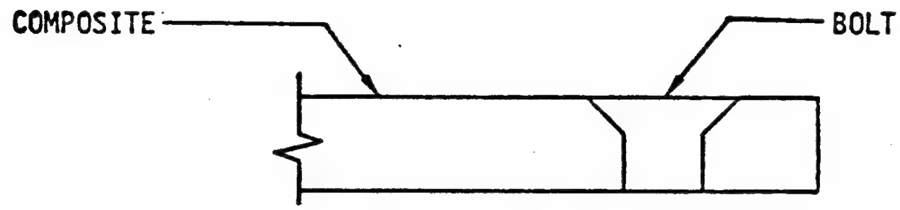
using the loads and frequency described above. Each specimen incorporated a different bearing concept around the bolt hole as shown in Figure 6-1. Each of the specimens exceeded 3.6 x 10^6 cycles without failure. Three specimens with 3/8 inch diameter Huck bolt blind fasteners were tested in fatigue using the same load spectrum described previously. Each of these specimens also incorporated one of the concepts shown in Figure 6-1. The fasteners in all three specimens failed in shear between 335,000 and 540,000 cycles. One specimen assembled with a Visulock blind fastener was tested in fatigue. This specimen incorporated a stepped insert. It was cycled more than 13 x 10^6 cycles without failure. One specimen was assembled with a torqued bolt installed at a 10 degree incline through the basic laminate (Concept #1). The configuration of the bolt head at the laminate surface was representative of the maximum slope of the bolts in the composite flap. The performance of this specimen was similar to the other torque bolt specimens and was loaded in excess of 10^7 cycles without failure.

Two torqued bolt specimens were loaded to failure after fatigue testing had been completed. The specimen bolted through the basic laminate (no doubler or insert) had an ultimate load of 11,860 lbs and failed by a combination of fastener bending and composite delaminations and shear-out. The second specimen was bolted through a laminate with a doubler and failed in single shear of 12,250 lbs. Both exceeded the 10,500 lbs design allowable load for the bolt.

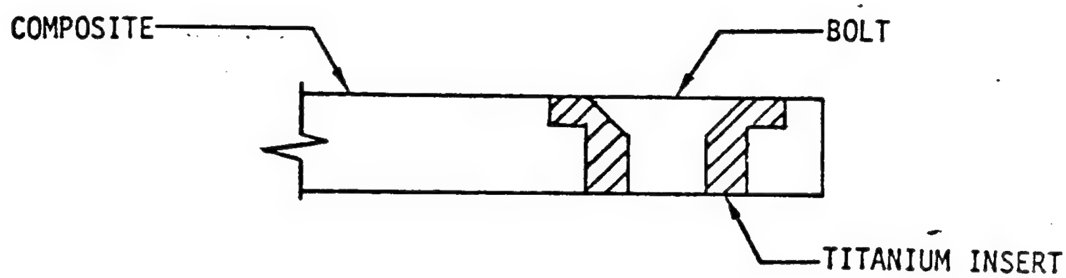
The results from the mechanical fastener tests demonstrated that in fatigue the torqued bolts are much superior to the Huck bolt blind fasteners. The Visulock blind fastener fatigue performance was equivalent to the torqued bolts. It was concluded that this fastener retained its compression loading across the joined interface in the fatigue environment. The specimen with the 10 degree inclined torqued bolt performed equivalent to the perpendicular torqued bolts and demonstrated that the composite flap load transfer fatigue requirements could be met by their application.

The results obtained in the fatigue tests also showed there was no improve-

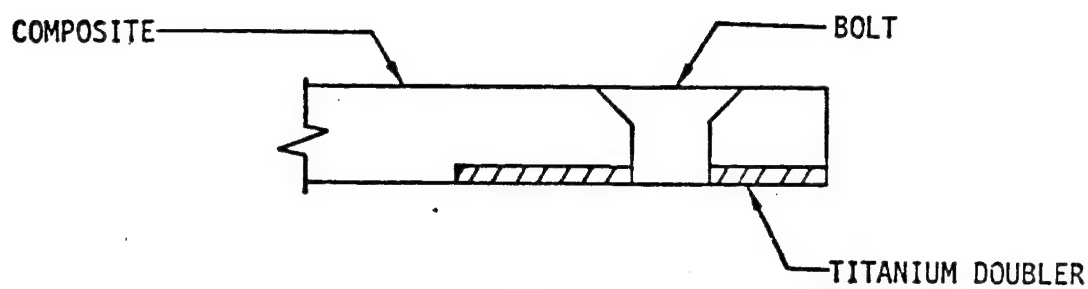
ment resulting from the use of the stepped inserts or doublers in the fastener bearing areas. Bolts passing through the basic laminates performed equivalent to those with the metal reinforcements.



CONCEPT NO. 1



CONCEPT NO. 2



CONCEPT NO. 3

FIGURE 6-1 COMPOSITE HOLE REINFORCEMENT CONCEPT

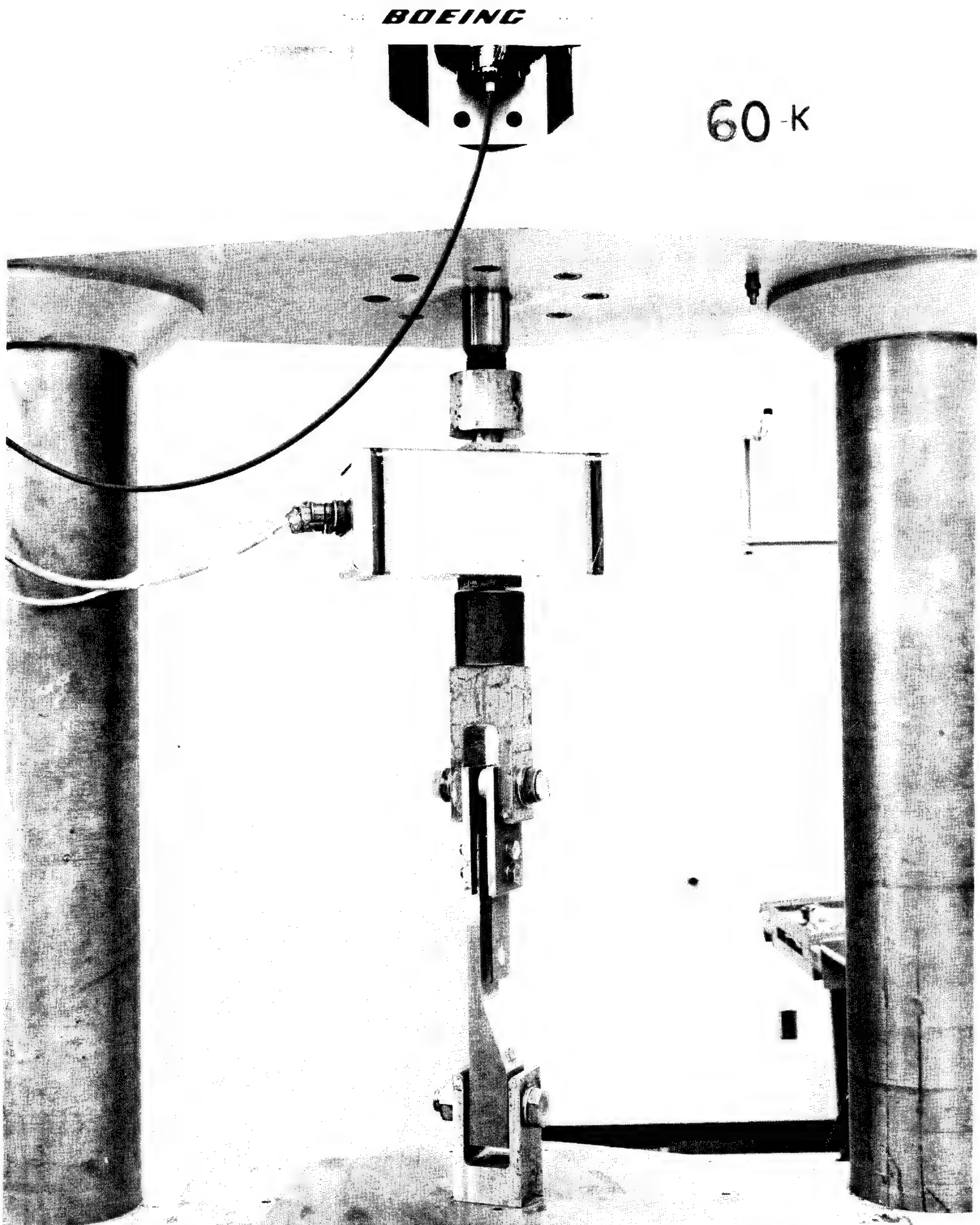
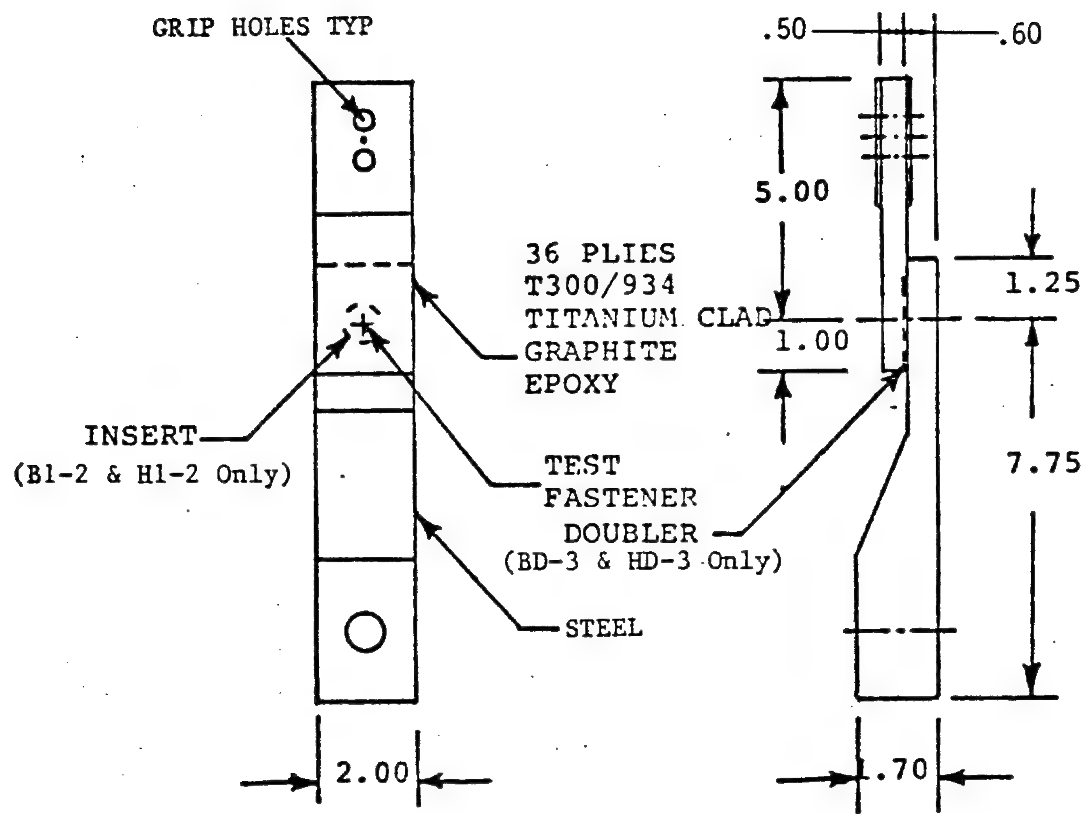


FIGURE 6-2 MECHANICAL FASTENER SPECIMEN FATIGUE TEST SETUP

TABLE 6-1

MECHANICAL FASTENER FATIGUE TEST DATA



SPECIMEN NUMBER AND CONCEPT	DESCRIPTION (SEE FIGURE 5-1)	LOAD MEAN ± ALT POUNDS	CYCLES TO FAILURE	TYPE OF FAILURE
B-1	B30SW6 BOLT	1507 ± 1493	6,047,000	NO FAILURE
BI-2	B30SW6 BOLT, WITH INSERT		3,640,000	NO FAILURE
BD-3	B30SW6 BOLT, WITH DOUBLER		6,617,000	NO FAILURE
H -1	3/8 HUCKBOLT		539,300	BOLT SHEAR
HI -2	3/8 HUCKBOLT WITH INSERT		335,700	BOLT SHEAR
HD -3	3/8 HUCKBOLT WITH DOUBLER		482,900	BOLT SHEAR
V -1	3/8 VISULOK		13,293,000	NO FAILURE
A -1	B30SW6-18 BOLT @ 10° ANGLE	1507 ± 1493	10,233,000	NO FAILURE

7.0 FINAL DESIGN AND ANALYSIS

A final design and supporting analysis of an inboard composite flap for the aft foil of the PCH-1 have been developed. This design incorporated graphite/epoxy covers clad with 10 mils titanium and a titanium crank-spar substructure assembly. An analysis of the composite flap was developed which emphasized the fatigue life characteristics of the design. A NASTRAN finite element analysis was also performed to establish load-deflection characteristics and to verify internal load distributions used in the detailed stress analysis.

7.1 FINAL DESIGN

A final design of an aft inboard starboard foil composite flap was developed which consisted of composite covers and a titanium substructure. Its assembly was accomplished by both bonding and the installation of mechanical fasteners.

The composite covers consisted of 36 plies of graphite/epoxy fabric oriented at ±45 degrees. The fabric designated was made of T300 fiber in a balanced weave. The resin consisted of Fiberite's 394 epoxy system. The cover laminates were clad with 10 mils of 6Al-4V titanium. This cladding was secondarily bonded in place with Hysol EA9628 adhesive at 250°F.

The crank and spar substructure was machined from 6Al-4V ELI grade titanium. A crank block and two spar blocks were initially rough machined and then electron beam (EB) welded into a single assembly prior to finish machining.

The flap was assembled by both bonding and the installation of mechanical attachments. After machining, all metal parts were cleaned, anodized and primed. The covers were then bonded to the titanium substructure in an autoclave with titanium mechanical fasteners installed.

Engineering drawings of the composite flap design have been prepared that

define all of the flap materials, processes, and details. These drawings are shown in Figures 7-1 through 7-7.

7.2 ANALYSIS

Two types of analyses were performed in support of the final design of the composite flap. A NASTRAN model was used to establish internal load distributions and cover shear flows. A fatigue analysis was performed on all critical titanium details to establish their life capabilities and their compliance with the requirements of the composite flap design.

A NASTRAN model of the composite flap was developed which incorporated approximately 900 nodes. A relatively fine grid was used in the area from the crank end to the first hinge. A coarser grid was used for the balance of the length. A sketch of the model node grid is shown in Figure 7-8. C-Quad-4 plate elements with specified orthotropic material properties accounted for the plate elements used to define the composite covers. Eight node solid elements were used to define the titanium substructure. The nodal network tied the covers and substructure at their interface. A post processing program was used to correct for the bending effects resulting from the node offsets to establish shear flows and stresses at the cover plate centroids.

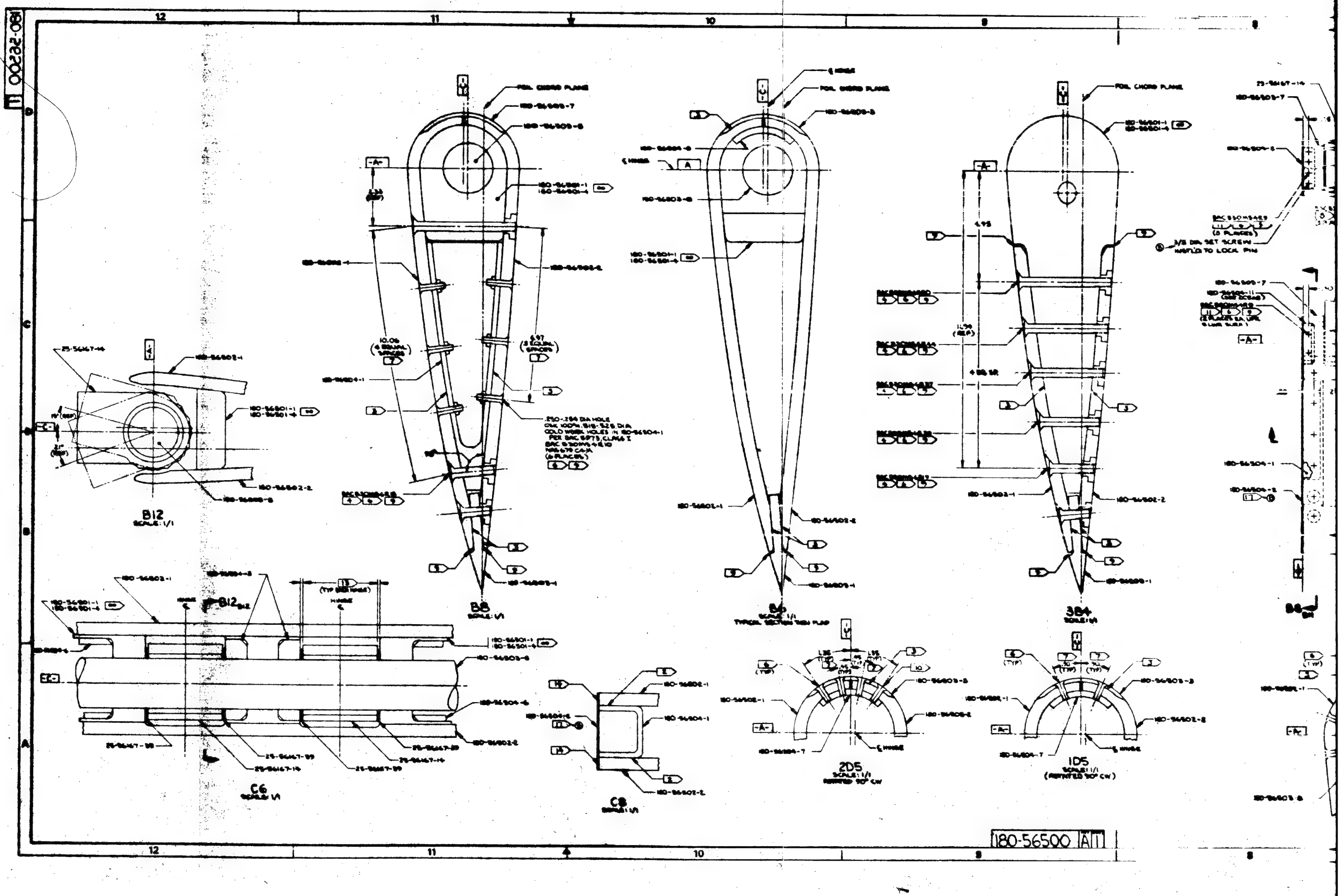
A uniform critical load of 6300 psf was applied resulting with a maximum torque of 509.4 inch-kips. This was about 8 percent higher than the critical hinge moment of 467.5 inch-kips calculated from the control-system-linkage load condition. The stresses and shear flows were determined for the 6300 psf uniform pressure loading. The shear flow contours for the upper and lower composite covers were developed. The maximum shear flow in the upper cover at the maximum fatigue loading, 40 percent critical load, was 2632 lb/in. The maximum shear flow in the lower cover was 2828 lb/in. The resulting maximum composite shear stress of 5795 psi was well below the 20 ksi plus endurance limit (reference Section 4.0) of the cover laminates. The shear flows were corrected to eliminate the bending effects due to the off-

set nodes. A typical plot of the corrected shear flows is shown in Figure 7-9.

The flap deflections were determined by the NASTRAN analysis. These results showed that maximum torsional deflection at 40 percent critical load was 10.6×10^{-7} radians. The deflection of the trailing edge at the inboard end of the flap (Node 5909) was 0.436 inches, which was less than the 0.53 inches maximum specified as a design requirement.

The feasibility component failed prematurely during fatigue testing. These failures occurred in some of the metal details. Emphasis was therefore placed on the fatigue analysis of the metal portions of the flap design. This analysis used the same design and test data presently used on Boeing aircraft and hydrofoil metal details.

The fatigue loads spectrum shown in Table 7-1 was used in the fatigue analysis. The shear, moment, and torsion diagrams used are shown in Figures 7-10 and 7-11. The life goal was 15 years or 15,000 hours of foilborne operation. A fatigue reliability factor of 1.0 was used. The fatigue life estimates were based on 95 percent probability of survival and that a typical failure would occur at four (4) times the 95 percent life. A summary of the fatigue lives calculated for the metal details is shown in Table 7-2. All are more than sufficient to meet the predicted PCH-1 hydrofoil flap requirement of 200 hours service exposure. A few areas are shy of the design life requirements of 15,000 hours specified for production hardware. This was essentially caused by the requirement which specified that the composit flap must be interchangeable with and remain within the envelope of existing steel flap. The areas which are shy are in the crank and will be blocked-up and fixtured in a manner which will permit the loads to bypass them and allow the flap to attain its design life goals. The fatigue analysis supporting thelife data summary shown in Table 7-2 was previously summarized and transmitted in Document D180-24630-1, "Development of an Advanced Composite Hydrofoil Flap - Phase II Final Design", Contract Number N00024-76-C-4233.



B12
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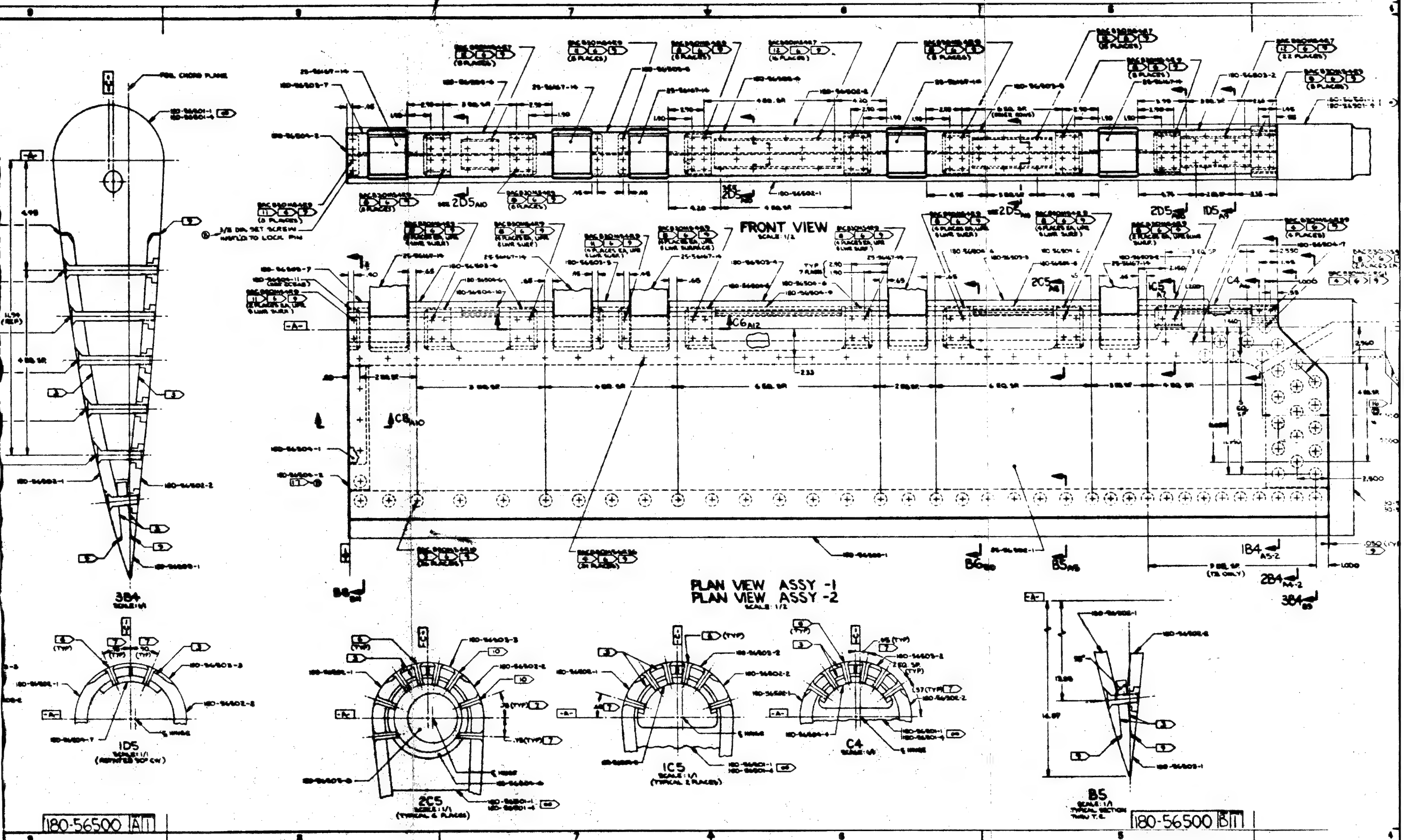
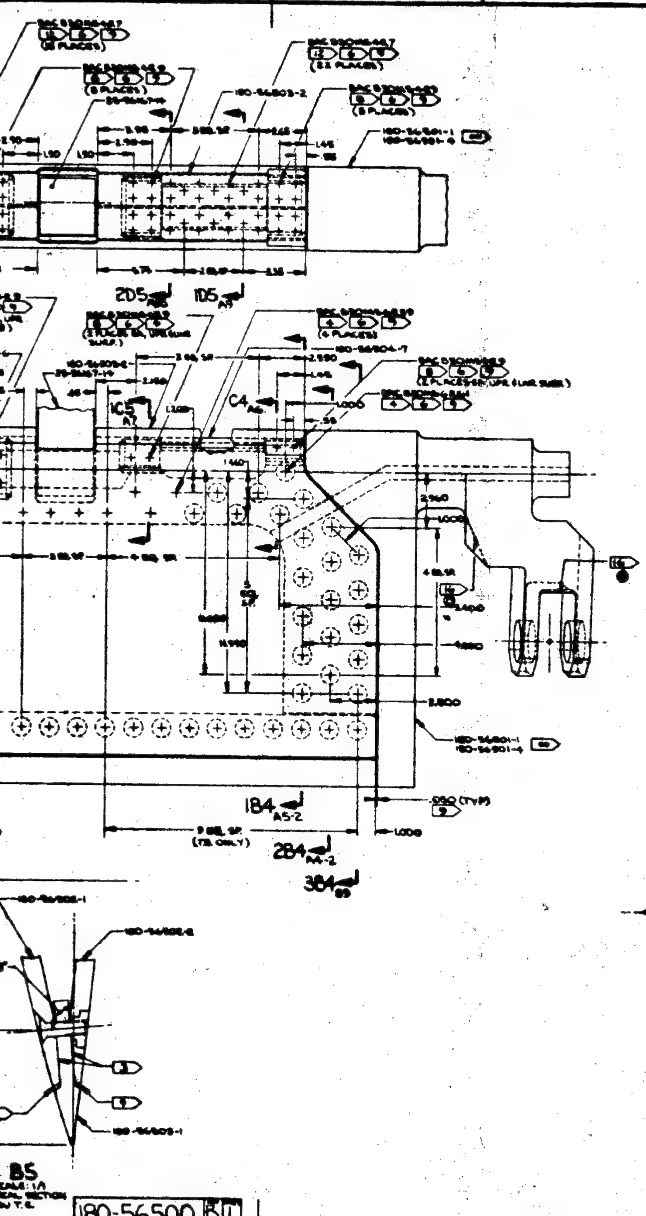
B8
SCALE: 1/1
B6
SCALE: 1/1
TYPICAL SECTION THRU FLAP
3B4
SCALE: 1/1
C6
SCALE: 1/1
C8
SCALE: 1/1
2D5
SCALE: 1/1
ROTATED 90° CW
1D5
SCALE: 1/1
(ROTATED 90° CW)
FOIL CHORD PLANE
3/8 DIA SET SCREW
180-56500 A1


FRONT VIEW
SCALE: 1/2
PLAN VIEW ASSY -1
PLAN VIEW ASSY -2
SCALE: 1/2
3B4
SCALE: 1/1
1D5
SCALE: 1/1
2C5
SCALE: 1/1
(TYPICAL 6 PLACES)
1C5
SCALE: 1/1
(TYPICAL 2 PLACES)
C4
SCALE: 1/1
B5
SCALE: 1/1
TYPICAL SECTION
THRU T.E.
180-56500 A11
180-56500 B11



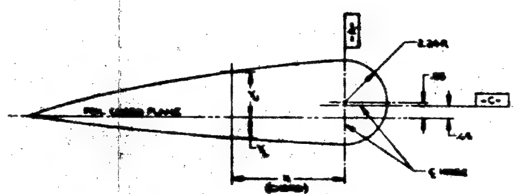


TABLE OF OFFSETS		
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[illegible]	2.79	1.27
[illegible]	2.44	1.08
[illegible]	1.96	0.86
[illegible]	1.38	0.60
[illegible]	0.65	0.29
[illegible]	0.00	0.00

A3
TYPICAL FLAP GEOMETRY

-2	—		TEST ONLY	1
-1	25-56160	PC(H)-1	TEST ONLY	1

APPLICATION

A	COMPLETELY REDRAWN
B	ADDED 18 AND LOC-TITE CRANK ASSY... TO PRO-VIDE CLEARANCE FOR FLAP INSTL. ADDED 17 TO PRO-VIDE... ADDED SET SCREW FOR LOCKING PIN (180-56503-8)

LIST OF MATERIALS CONTINUED ON SHEET 2

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1	1	BACB30MS4R18	BOLT	
26	26	BACB30MS6R10	BOLT	
150	150	BACB30MS4R9	BOLT	
64	64	BACB30MS4R7	BOLT	
10	10	25-56167-39	SHIM	A11
5	5	25-56167-14	HINGE BLOCK ASSY	A11
1	1	180-56504-11	DOUBLER-INNER-LE	C6
1	1	180-56504-10	DOUBLER-INNER-LE	C7
1	1	180-56504-9	DOUBLER, INNER-L.E.	C6
1	1	180-56504-8	DOUBLER, INNER-L.E.	C8
1	1	180-56504-7	DOUBLER, INNER-L.E.	C4
6	6	180-56504-6	DOUBLER, INNER-L.E.	C7 C6 C8
1	1	180-56504-5	DOUBLER, INNER-L.E.	A7
1	1	180-56504-4	DOUBLER, INNER-L.E.	A6
2	2	180-56504-3	SPACER	B12
1	1	180-56504-2	END PLATE	B8
1	1	180-56504-1	CLOSURE RIB	B8
1	1	180-56503-8	HINGE PIN	C7
1	1	180-56503-7	DOUBLER-L.E.	C8
1	1	180-56503-6	DOUBLER-L.E.	C7
1	1	180-56503-5	DOUBLER-L.E.	C7
1	1	180-56503-4	DOUBLER-L.E.	C6
1	1	180-56503-3	DOUBLER-L.E.	C5
1	1	180-56503-2	DOUBLER-L.E.	C5
1	1	180-56503-1	STIFFENER-TRAILING EDGE	B6
1	1	180-56502-2	LWR COVER ASSY	B9
1	1	180-56502-1	UPR COVER ASSY	B9
1		180-56501-4	SPAR/CRANK ASSY	B4
	1	180-56501-1	SPAR/CRANK ASSY	B4
—		-2	FLAP ASSY	B6
	—	-1	FLAP ASSY	B6

N00024-76-C-4233

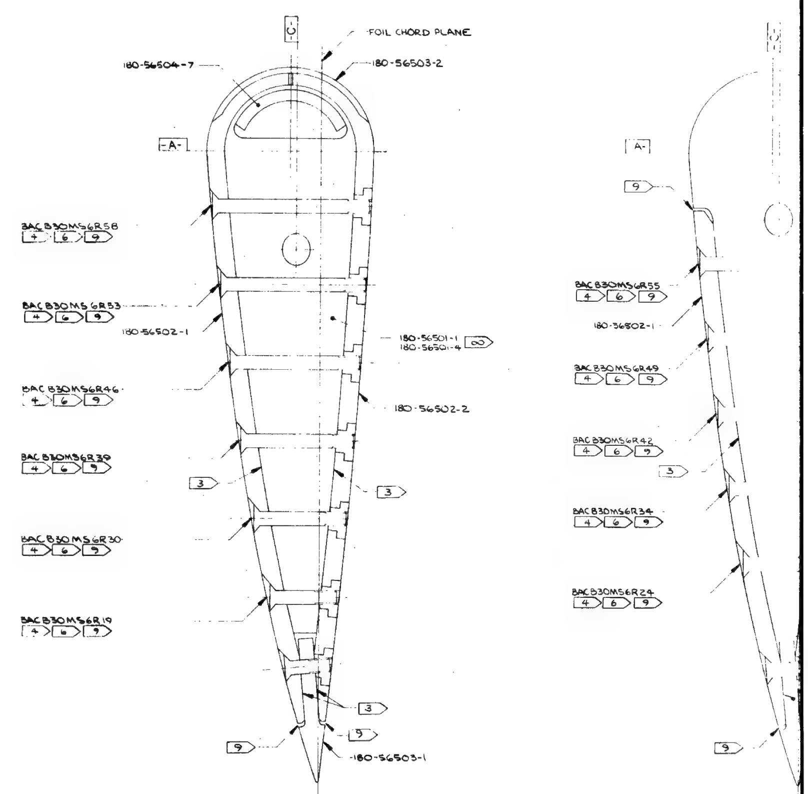
FLAP ASSEMBLY -
INBD STBD CONTROL FLAP
PC(H)-1 HYDROFOIL

J 180-56500

FIGURE

180-56500 B

75
D321-51319-1



1B4-1
SCALE: 1/1

NOTES

1 SPECIFICATIONS AND STANDARDS FOR THE CONTROL OF MANUFACTURING OPERATIONS (AS APPLICABLE)

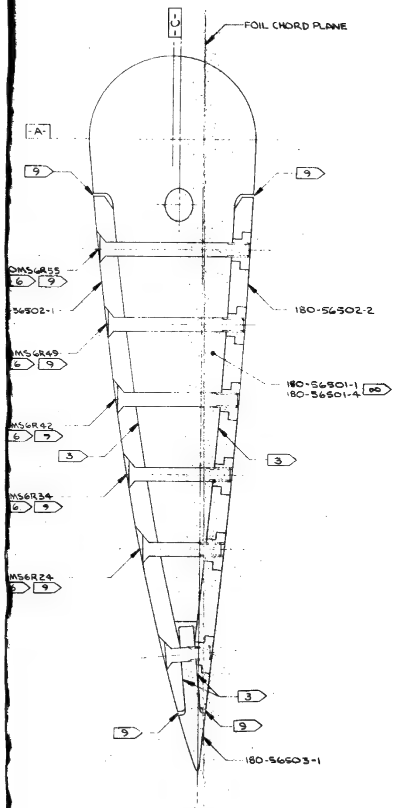
FORM, STRAIGHTEN & FIT METAL PARTS PER BAC 5300 — BOLT & NUT INSTALLATION PER BAC 5009

RIVET INSTALLATION & SYMBOLS PER BAC 5004 — PART MARKING PER BAC 5307

FINISH CODES PER DOCUMENT D2-8000

REV STATUS	
SH	LTR

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED



2B4-1
SCALE: 1/1

QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD -2	QTY REQD -1	FIND NUMBER	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	ZONE	MATERIAL AND SPECIFICATION	CODE IDENT NO	HT TR	FINISH	PT MK	REV LTR
				A/R	A/R		BMS5-101	ADHESIVE							
				31	31		BACB30MS6R56	BOLT-100° HD							
				6	6		NAS679C4M	NUT-SELF LOCKING							
				1	1		BACB30MS6R61	BOLT-100° HD							
				4	4		BACB30MS6R59								
				1	1		BACB30MS6R58								
				1	1		BACB30MS6R55								
				1	1		BACB30MS6R53								
				1	1		BACB30MS6R50								
				1	1		BACB30MS6R49								
				1	1		BACB30MS6R46								
				1	1		BACB30MS6R44								
				1	1		BACB30MS6R42								
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				1	1		BACB30MS6R37								
				1	1		BACB30MS6R34								
				1	1		BACB30MS6R30								
				1	1		BACB30MS6R29								
				1	1		BACB30MS6R24								
				2	2		BACB30MS6R19	BOLT-100° HD							

PARTS LIST

FASTENER CODES

PART NUMBER	NEXT ASSY	USED ON	EFFECTIVITY	DWG SH NUMBER	REV LTR

APPLICATION

DIMENSIONING & TOLERANCING PER ANSI (USASI) Y14.5
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES: ANGLES ±
DECIMALS .XX ±
DECIMALS .XXX ±

REVIEW & APPROVAL: DWG QUAL; STRUCT; MATL & PROC; CHANGE/ITEM NUMBER

CONTRACT NUMBER N00024-76-C-4233
DWN Don Good 10/30/77
CHK
ENGR
ORG
PROJECT APPROVAL

THE BOEING COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124

FLAP ASSEMBLY – INBD STBD CONTROL FLAP PC(H)-1 HYDROFOIL

SIZE J CODE IDENT NO 180-56500
SCALE NOTED SH 2 OF 2

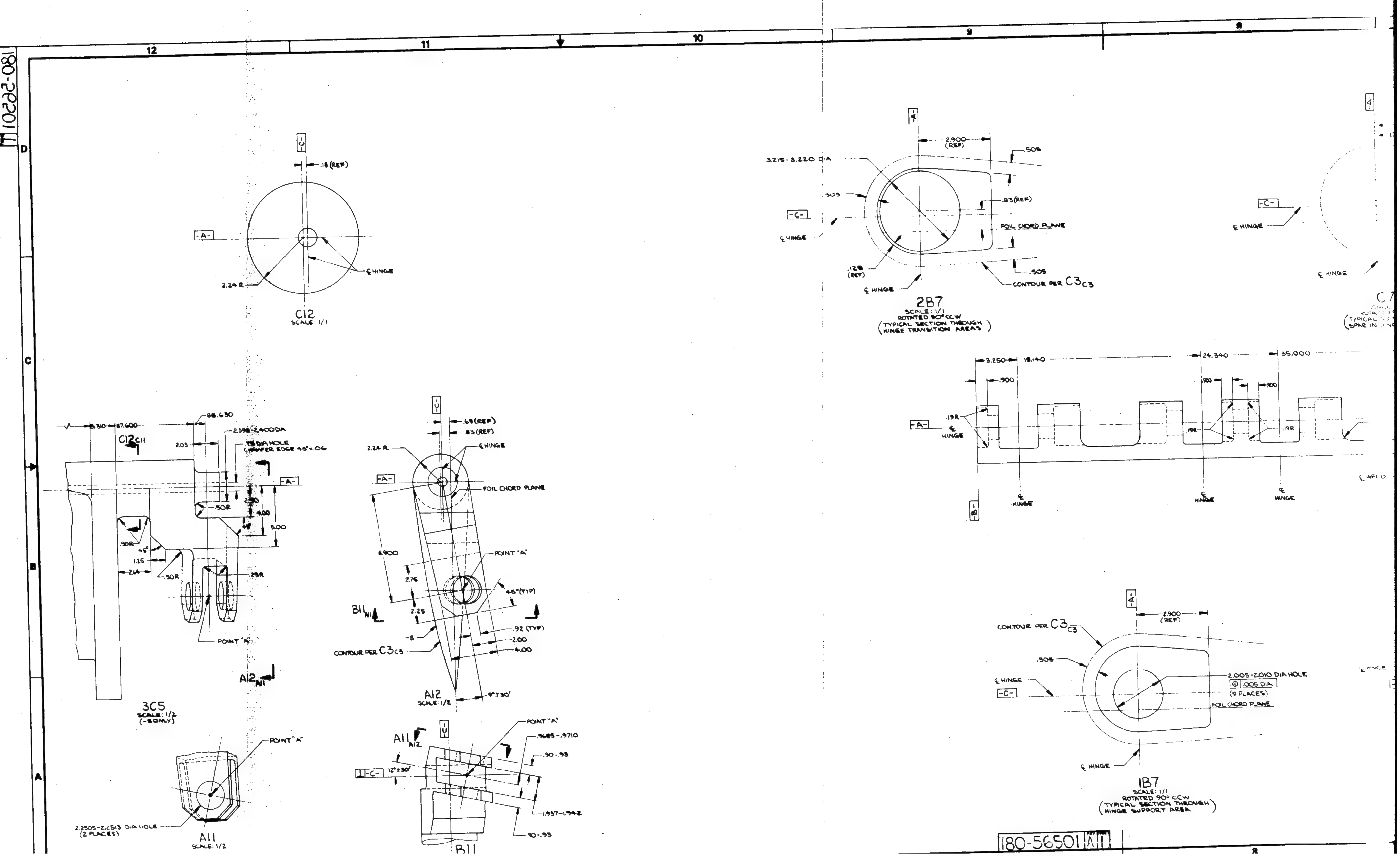
180-56500 REV 2

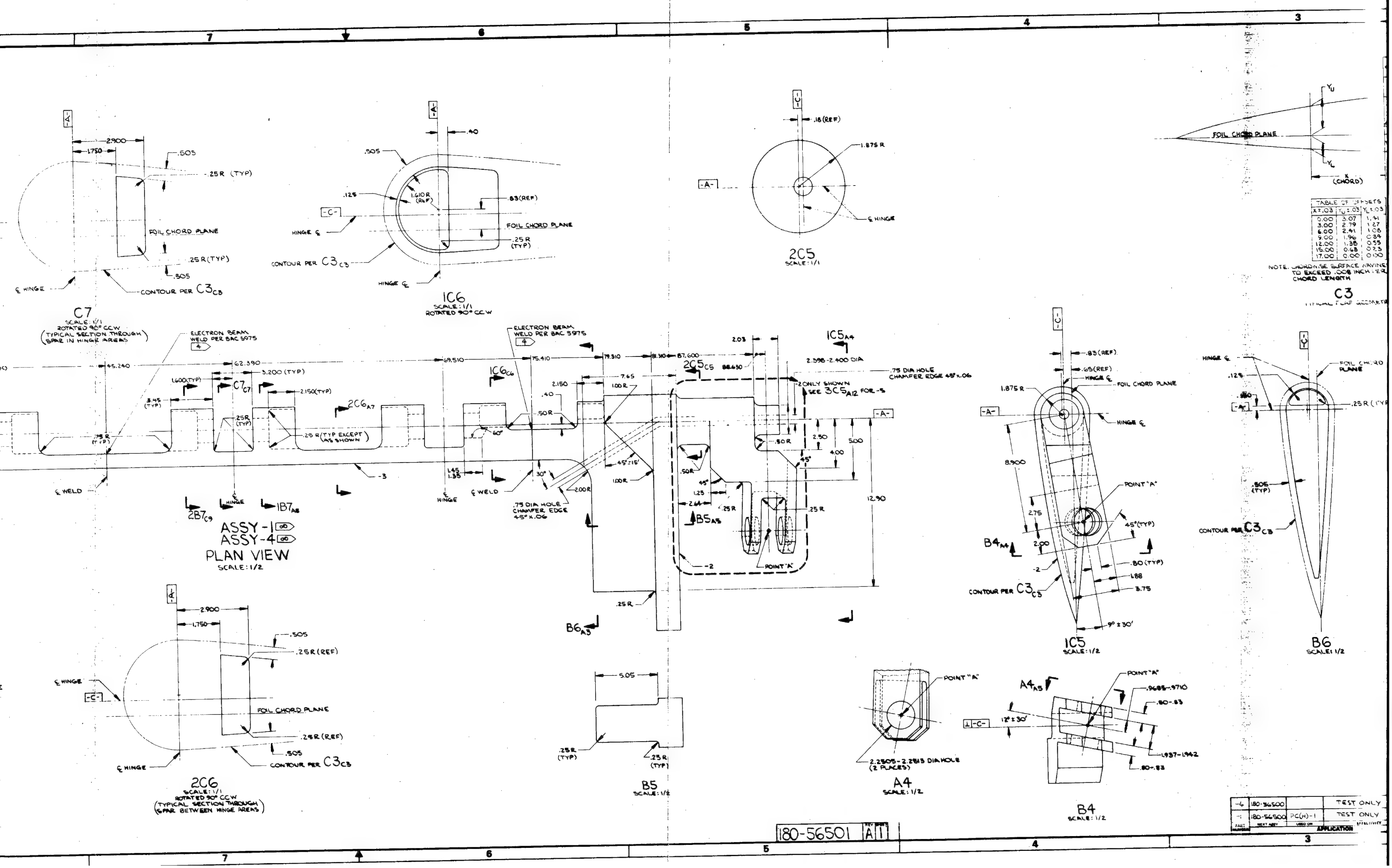
DWG ORIG BY (ORG)

DRAWING RECORDS CLERK

180-56500

76
D321-51319-1


C12
SCALE: 1/1
.18 (REF)
2.24 R
℄ HINGE
3C5
SCALE: 1/2
(-5 ONLY)
A11
SCALE: 1/2
2.2505-2.2513 DIA HOLE
(2 PLACES)
POINT "A"
A12
SCALE: 1/2
B11
CONTOUR PER C3 C3
FOIL CHORD PLANE
8.900
2.76
2.25
.92 (TYP)
2.00
4.00
45° (TYP)
9°±30'
.65 (REF)
.83 (REF)
.9685-.9710
.90-.93
1.937-1.942
12°±30'
2.398-2.400 DIA
88.630
87.600
81.310
2.03
.50R
.25R
1.25
2.14
45°
2.50
4.00
5.00
2B7
SCALE: 1/1
ROTATED 90° CCW
(TYPICAL SECTION THROUGH HINGE TRANSITION AREAS)
3.215-3.220 DIA
2.900 (REF)
.505
.83 (REF)
.128 (REF)
3.250
18.140
24.340
35.000
.900
.19R
1B7
SCALE: 1/1
ROTATED 90° CCW
(TYPICAL SECTION THROUGH HINGE SUPPORT AREA)
2.005-2.010 DIA HOLE
.005 DIA
(9 PLACES)
180-56501 A11
180-56501 A11



X ±.03	Y_U ±.03	Y_L ±.03
0.00	3.07	1.41
3.00	2.79	1.27
6.00	2.41	1.08
9.00	1.96	0.89
12.00	1.38	0.55
15.00	0.68	0.23
17.00	0.00	0.00

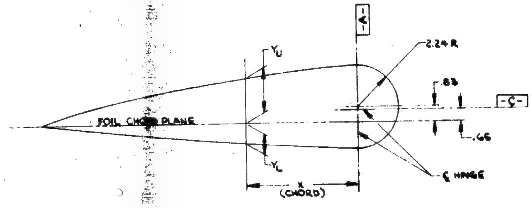


TABLE OF OFFSETS		
X ±.03	Y_U ±.03	Y_L ±.03
0.00	3.07	1.41
3.00	2.79	1.27
6.00	2.41	1.06
9.00	1.96	0.84
12.00	1.38	0.55
15.00	0.68	0.23
17.00	0.00	0.00

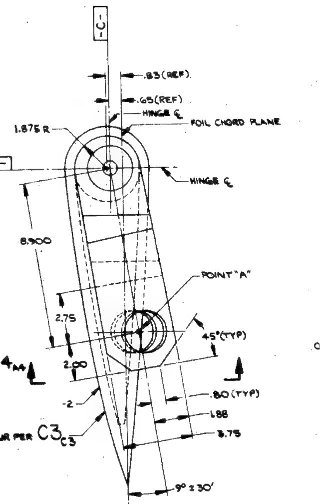
NOTE: CHORDWISE SURFACE WAVINESS NOT TO EXCEED .008 INCH PER INCH OF CHORD LENGTH

C3
TYPICAL FLAP GEOMETRY

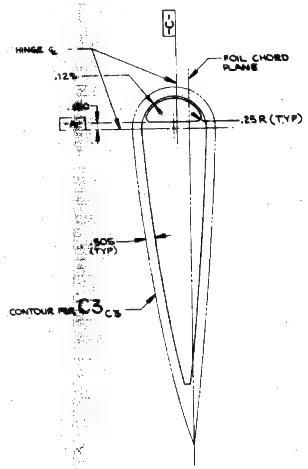
NOTES

1. SPECIFICATIONS AND STANDARDS FOR THE CONTROL OF MANUFACTURING OPERATIONS (AS APPLICABLE).
   - SURFACE ROUGHNESS SYMBOLS PER BACD 2007
   - WELDING AND BRAZING SYMBOLS PER BACD 2002
   - FORM, STRAIGHTEN & FIT METAL PARTS PER BAC [illegible]
   - MATERIAL SUBSTITUTIONS & EQUIVALENTS PER BAC [illegible]
   - PART MARKING PER BAC [illegible]
   - BOLT & NUT INSTALLATION PER BAC [illegible]
   - FINISH CODES PER DOCUMENT [illegible]
   - RIVET INSTALLATION & SYMBOLS PER BAC [illegible]
2. RADIOGRAPHIC INSPECT ALL WELDS PER BAC 5915
3. PENETRANT INSPECT ALL WELDS PER BAC 5423
4. AFTER EB WELDING, STRESS RELIEVE PER BAC 5613 EXCEPT TEMPERATURE CYCLE IS AS FOLLOWS: 1350 °F FOR 2 HOURS, AIR COOL.
5. 6AI-4V(ELI) TITANIUM PER MIL-T-9047, COMP 7 ⟨6⟩
6. PROCURED PER SPEC PLUS ADDITIONAL HEAT TREAT AS FOLLOWS: 1) ANNEAL AT 1900 °F FOR 20 MIN THROUGHOUT, AIR COOL 2) STRESS RELIEVE AT 1350 °F FOR 2 HOURS, AIR COOL
7. ANODIZE PER BAC 5890 & PRIME WITH BMS 5-89 PER BAC 5546
   LIMITED-SEE LIST OF MATERIALS FOR RELEASE
8. BREAK ALL SHARP EDGES .010-.030 R (CHAMFER OPTIONAL).

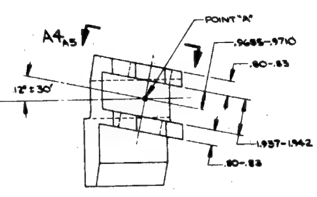
REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
A	COMPLETELY REDRAWN	10/6/77	



1C5
SCALE: 1/2



B6
SCALE: 1/2



B4
SCALE: 1/2

QTY	QTY	QTY	QTY	QTY -4	QTY -1	CODE IDENT NO	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	ZONE	MATERIAL AND SPECIFICATION	HT TR	FINISH	PT NO	REV LTR
				1			-5	SPAR/CRANK	A12	⟨6⟩				
				—			-4	SPAR/CRANK ASSY	B7					
				1	1		-3	SPAR	B7	⟨5⟩			R	A
					1		-2	SPAR/CRANK	B6	⟨5⟩			R	A
					—		-1	SPAR/CRANK ASSY	B7			⟨7⟩	R	A

PARTS LIST

PART NUMBER	NEXT ASSY	USED ON	EFFECTIVITY
-4	180-56500		TEST ONLY
-1	180-56900	PC(H)-1	TEST ONLY

APPLICATION

FASTENER CODES

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES: ANGLES ± 1/2°
DECIMALS .XX ± .03
DECIMALS .XXX ± .010

CONTRACT NUMBER N00024-76-C-4233
DRN Don Goop 8/4/77
CHK
ENGR S. C[illegible] 8 18 77

THE BOEING COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON

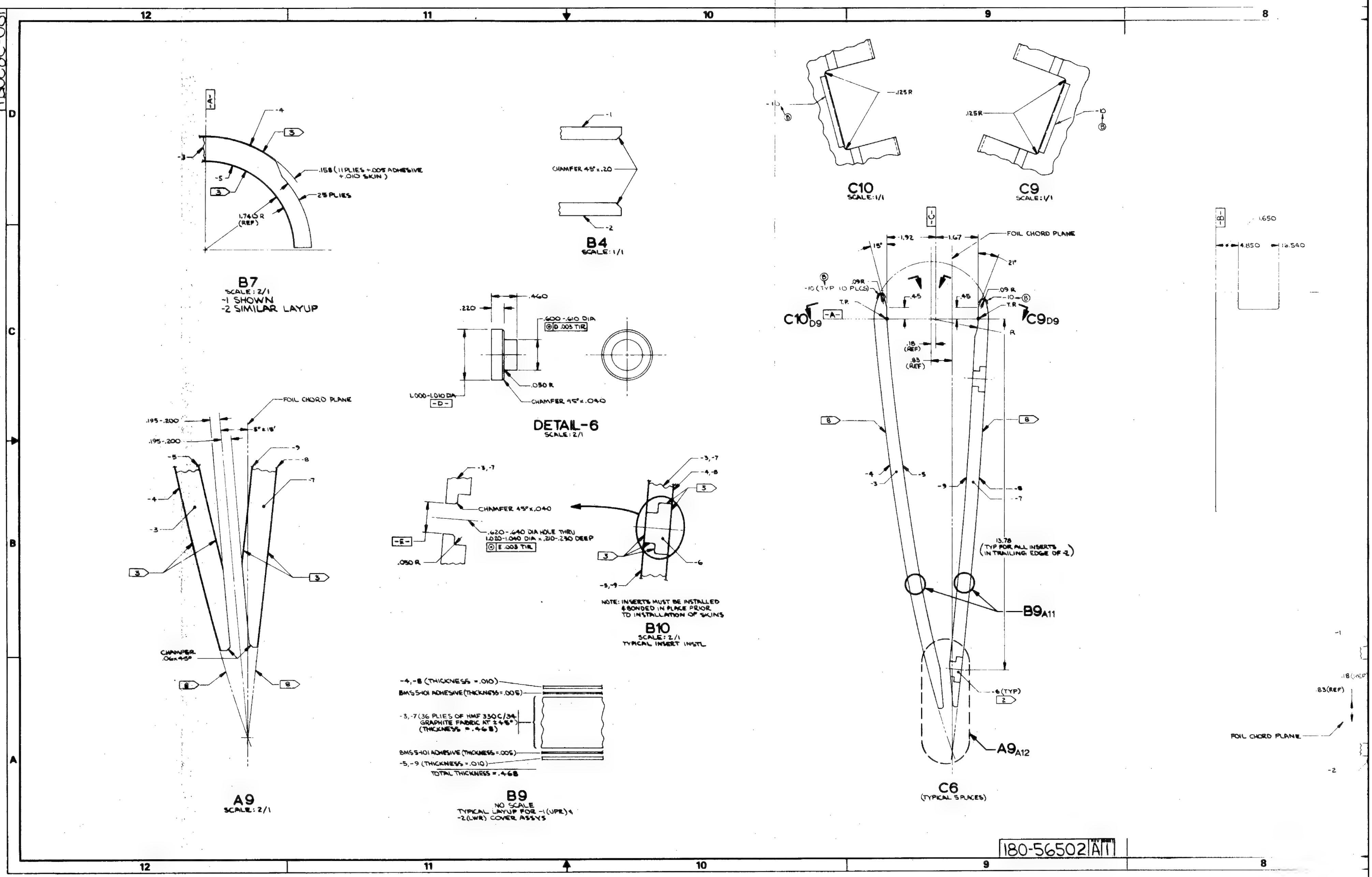
SPAR/CRANK ASSY-
INBD STBD CONTROL FLAP,
PC(H)-1 HYDROFOIL

SIZE J
180-56501
SCALE NOTED
SH 1 OF 1

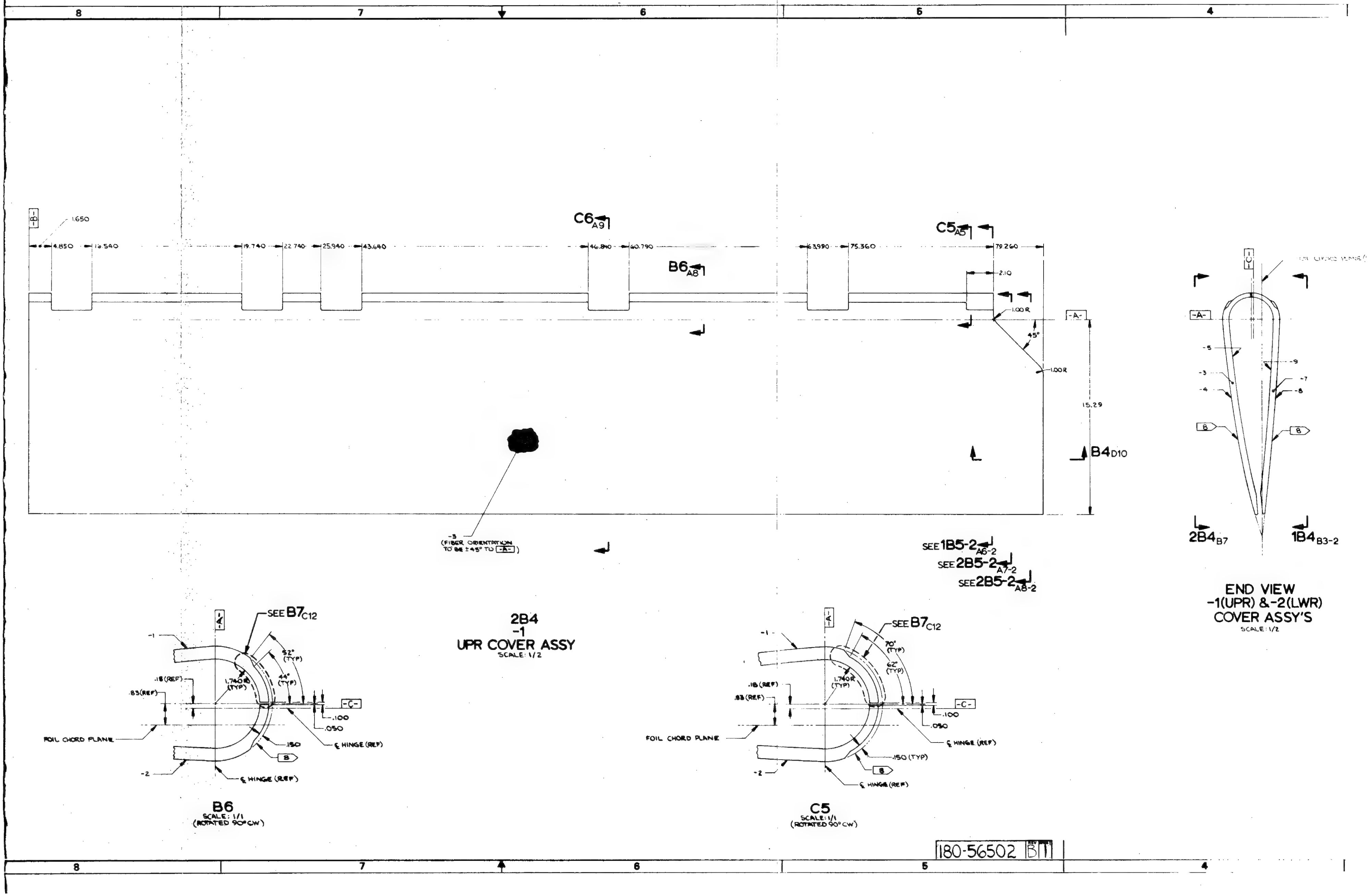
FIGURE 7-3

180-56501 A

180-56501



B7
SCALE: 2/1
-1 SHOWN
-2 SIMILAR LAYUP
.158 (11 PLIES + .005 ADHESIVE + .010 SKIN)
25 PLIES
1.745 R (REF)
B4
SCALE: 1/1
CHAMFER 45° x .20
DETAIL-6
SCALE: 2/1
.600-.610 DIA
1.000-1.010 DIA
.050 R
CHAMFER 45° x .040
C10
SCALE: 1/1
C9
SCALE: 1/1
.125 R
FOIL CHORD PLANE
A9
SCALE: 2/1
CHAMFER .06 x 45°
.620-.640 DIA HOLE THRU
1.020-1.040 DIA x .210-.230 DEEP
NOTE: INSERTS MUST BE INSTALLED & BONDED IN PLACE PRIOR TO INSTALLATION OF SKINS
B10
SCALE: 2/1
TYPICAL INSERT INSTL
-4, -8 (THICKNESS = .010)
BMS5-101 ADHESIVE (THICKNESS = .005)
-3, -7 (36 PLIES OF HMF 330C/34 GRAPHITE FABRIC AT ±45°) (THICKNESS = .468)
BMS5-101 ADHESIVE (THICKNESS = .005)
-5, -9 (THICKNESS = .010)
TOTAL THICKNESS = .468
B9
NO SCALE
TYPICAL LAYUP FOR -1 (UPR) & -2 (LWR) COVER ASSYS
13.78 (TYP FOR ALL INSERTS IN TRAILING EDGE OF -2)
-6 (TYP)
C6
(TYPICAL 5 PLACES)
B9 A11
A9 A12
C10 D9
C9 D9
180-56502 A11
180-29205



-B-
1.650
4.850
16.540
19.740
22.740
25.940
43.640
46.840
60.790
63.990
75.360
79.260
2.10
C6 A9
B6 A8
C5 A5
1.00 R
45°
-A-
15.29
B4 D10
-3 (FIBER ORIENTATION TO BE ±45° TO -A-)
SEE 1B5-2 A6-2
SEE 2B5-2 A7-2
SEE 2B5-2 A8-2
2B4
-1
UPR COVER ASSY
SCALE: 1/2
-C-
-5
-3
-4
-9
-7
-8
B
2B4 B7
1B4 B3-2
END VIEW
-1(UPR) & -2(LWR)
COVER ASSY'S
SCALE: 1/2
SEE B7 C12
52° (TYP)
44° (TYP)
1.740 R (TYP)
.18 (REF)
.83 (REF)
FOIL CHORD PLANE
.100
.050
.150
℄ HINGE (REF)
-1
-2
B6
SCALE: 1/1
(ROTATED 90° CW)
70° (TYP)
62° (TYP)
.150 (TYP)
C5
SCALE: 1/1
(ROTATED 90° CW)
180-56502 B

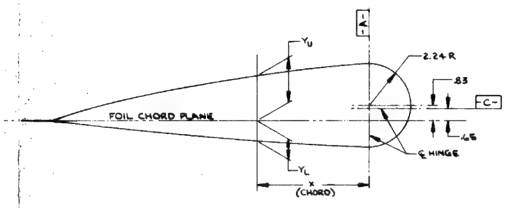
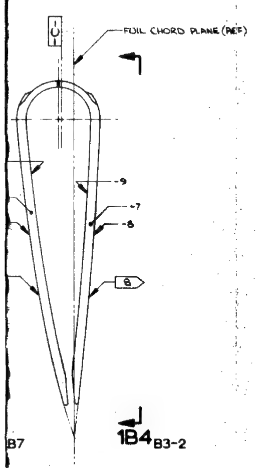


TABLE OF OFFSETS		
X±.03	Y_U±.03	Y_L±.03
0.00	3.07	1.41
3.00	2.79	1.27
6.00	2.41	1.08
9.00	1.96	0.84
12.00	1.38	0.55
15.00	0.68	0.23
17.00	0.00	0.00

NOTE: CHORDWISE SURFACE WAVINESS NOT TO EXCEED .008 INCH PER INCH OF CHORD LENGTH.

C3
TYPICAL FLAP GEOMETRY



END VIEW
-1(UPR) & -2(LWR)
COVER ASSY'S
SCALE: 1/2

NOTES

1 SPECIFICATIONS AND STANDARDS FOR THE CONTROL OF MANUFACTURING OPERATIONS (AS APPLICABLE):
SURFACE ROUGHNESS SYMBOLS PER BACD 2007 — PART MARKING PER BAC 5307
WELDING AND BRAZING SYMBOLS PER BACD 2002 — BOLT & NUT INSTALLATION PER BAC 5009
FORM, STRAIGHTEN & FIT METAL PARTS PER BAC 5300 — FINISH CODES PER DOCUMENT D6-5000
MATERIAL SUBSTITUTIONS & EQUIVALENTS PER BAC 5005 — RIVET INSTALLATION & SYMBOLS PER BAC 5004

2 SEE B10 B10 FOR TYPICAL INSERT INSTALLATION

3 ADHESIVE BOND WITH BMS 5-101, TYPE II, GRADE 10 PER BAC 5514. MULTIPLE LAYERS OF ADHESIVE MAY BE USED WHERE ADDITIONAL THICKNESS IS REQUIRED. RECORD ALL AREAS WHERE ADDITIONAL THICKNESS IS REQUIRED. USE HYSOL 9628.

4 6AL-4V TITANIUM PER MIL-T-9046, TYPE II, COMP. C

5 HMF 330C/34 PREPREG FABRIC FIBERITE CORP., WINONA, MINN.

6 ANODIZE PER BAC 5890 & PRIME WITH BMS 5-89 PER BAC 5646

7 BMS 5-101B, TYPE II, GRADE 10, HYSOL 9628.

8 CONTOUR PER C3 C3

9 BOND WITH EPON 828 → ⓑ

REV STATUS	
SH	LTR

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	COMPLETELY REDRAWN		
D-11	B	INSTL. LEAD'G EDGES AT BEARING CUT OUTS - 10 PLCS.	1-22-79	

PARTS LIST

QTY REQD -2	QTY REQD -1	CODE IDENT NO	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	ZONE	MATERIAL AND SPECIFICATION	HT TR	FINISH
5	5		-10	LEADING EDGE		.010 × 0.50 × 2.88 4 8		
AR	AR		BMS 5-101B	ADHESIVE		7		
1			-9	SKIN-INNER	C4-1	.010 × 21.0 × 80.0 4		6
1			-8	SKIN-OUTER	C4-1	.010 × 21.0 × 80.0 4		6
1			-7	COMPOSITE LAYUP-LWR	C4-1	36 PLIES 5		
89			-6	INSERT	C11-1	.50 × 1.00 DIA 4		6
	1		-5	SKIN-INNER	C4-1	.010 × 21.0 × 80.0 4		6
	1		-4	SKIN-OUTER	C4-1	.010 × 21.0 × 80.0 4		6
	1		-3	COMPOSITE LAYUP-UPR	C4-1	36 PLIES 5		
—			-2	COVER ASSY-LWR	B3-2			
	—		-1	COVER ASSY-UPR	B6-1			

PART NUMBER	NEXT ASSY	USED ON	EFFECTIVITY	SHEET NUMBER
-2	180-56500	PC(H)-1	TEST ONLY	1 & 2
-1	180-56500	PC(H)-1	TEST ONLY	1 & 2

APPLICATION

FASTENER CODES

DIMENSIONING & TOLERANCING PER ANSI Y14.5
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES: ANGLES ± 1/2°
DECIMALS .XX ± .03
DECIMALS .XXX ± .010

CONTRACT NUMBER N00024-76-C-4233
DR Don Good 12/6/77
CHK J. Olsen 1/23/78

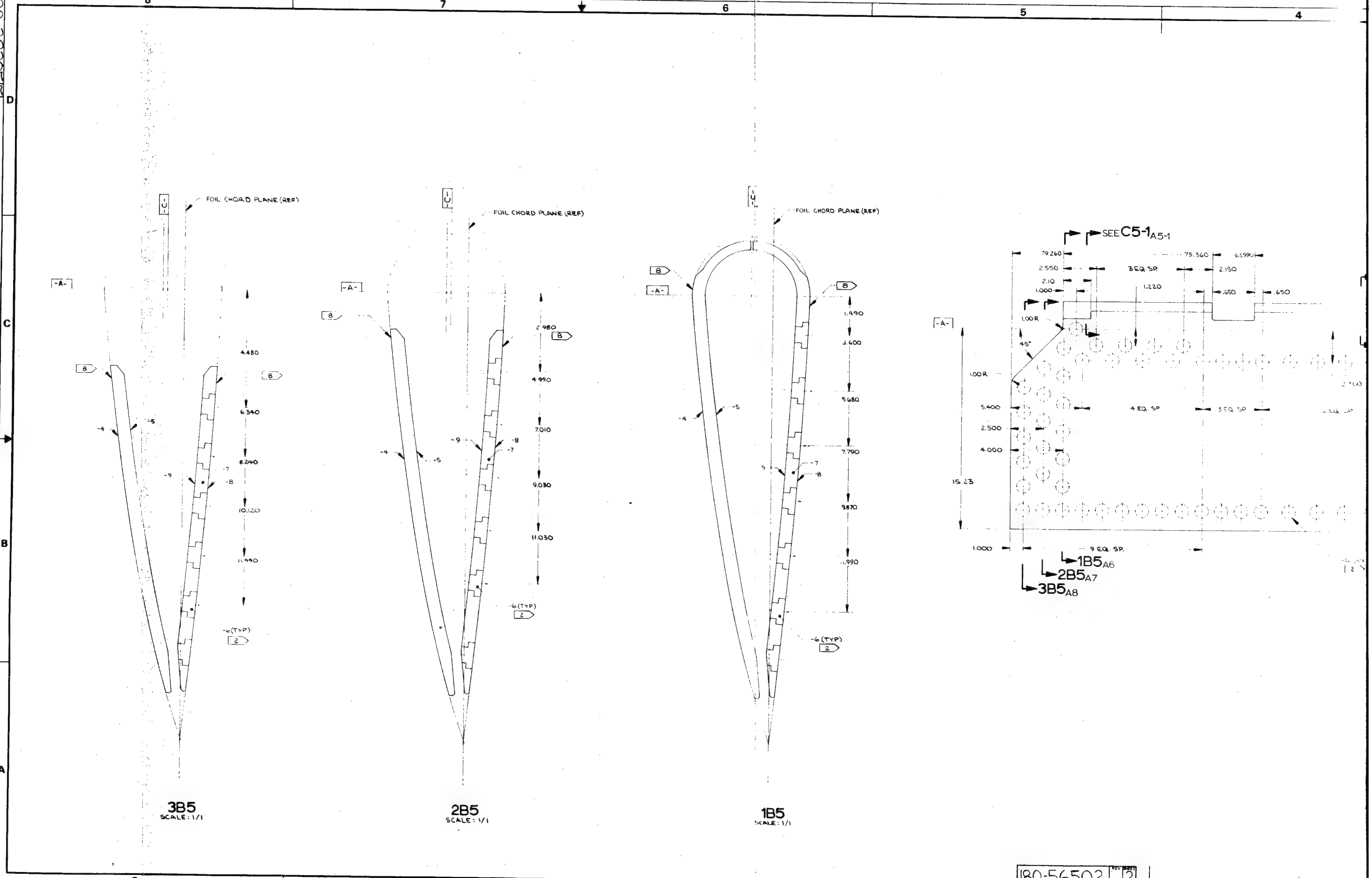
THE BOEING COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON

COVER ASSY-UPR & LWR, INBD STBD CONTROL FLAP, PC(H)-1 HYDROFOIL

SIZE J — 180-56502
SCALE NOTED — SH 1 OF 2

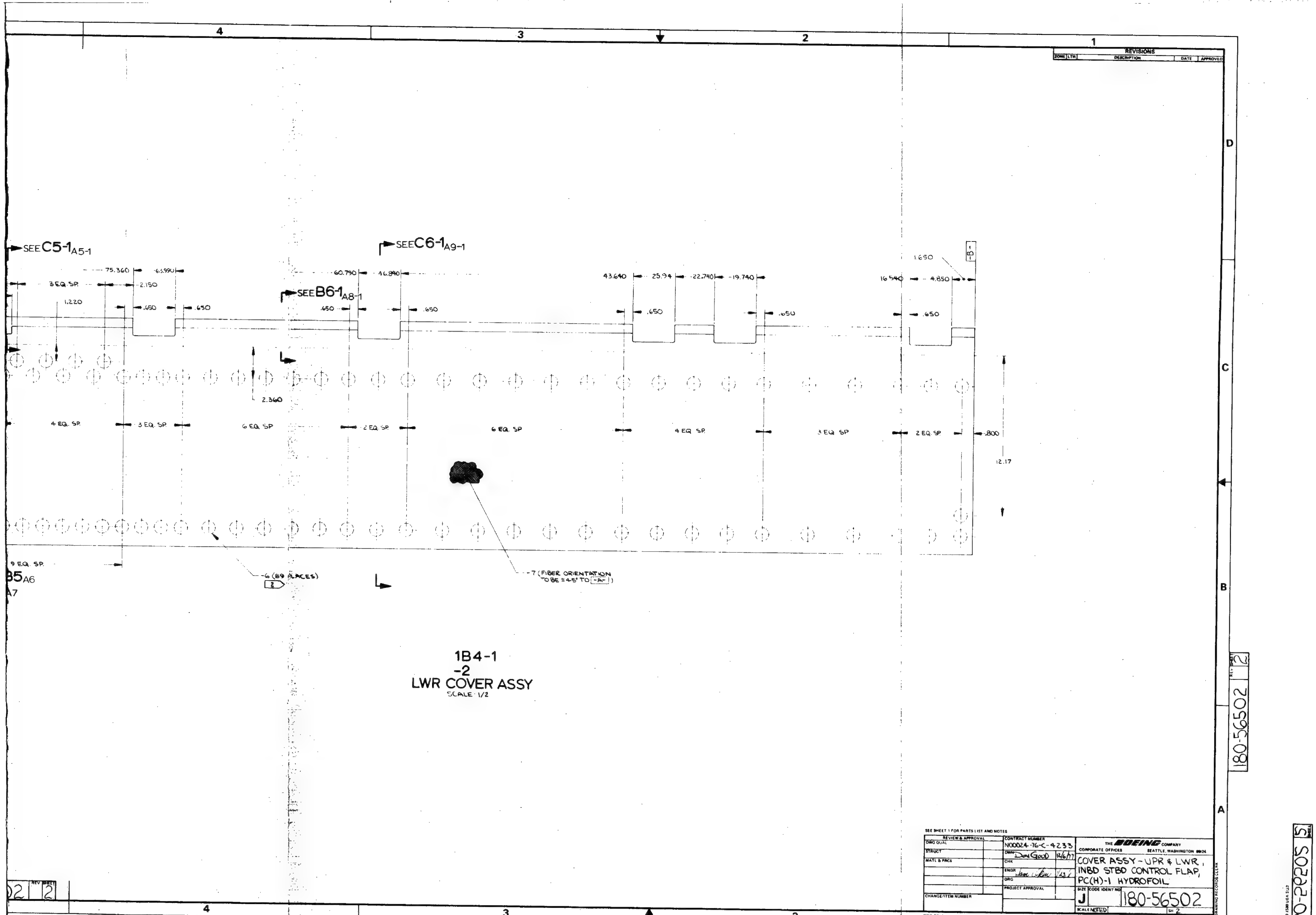
180-56502 B1

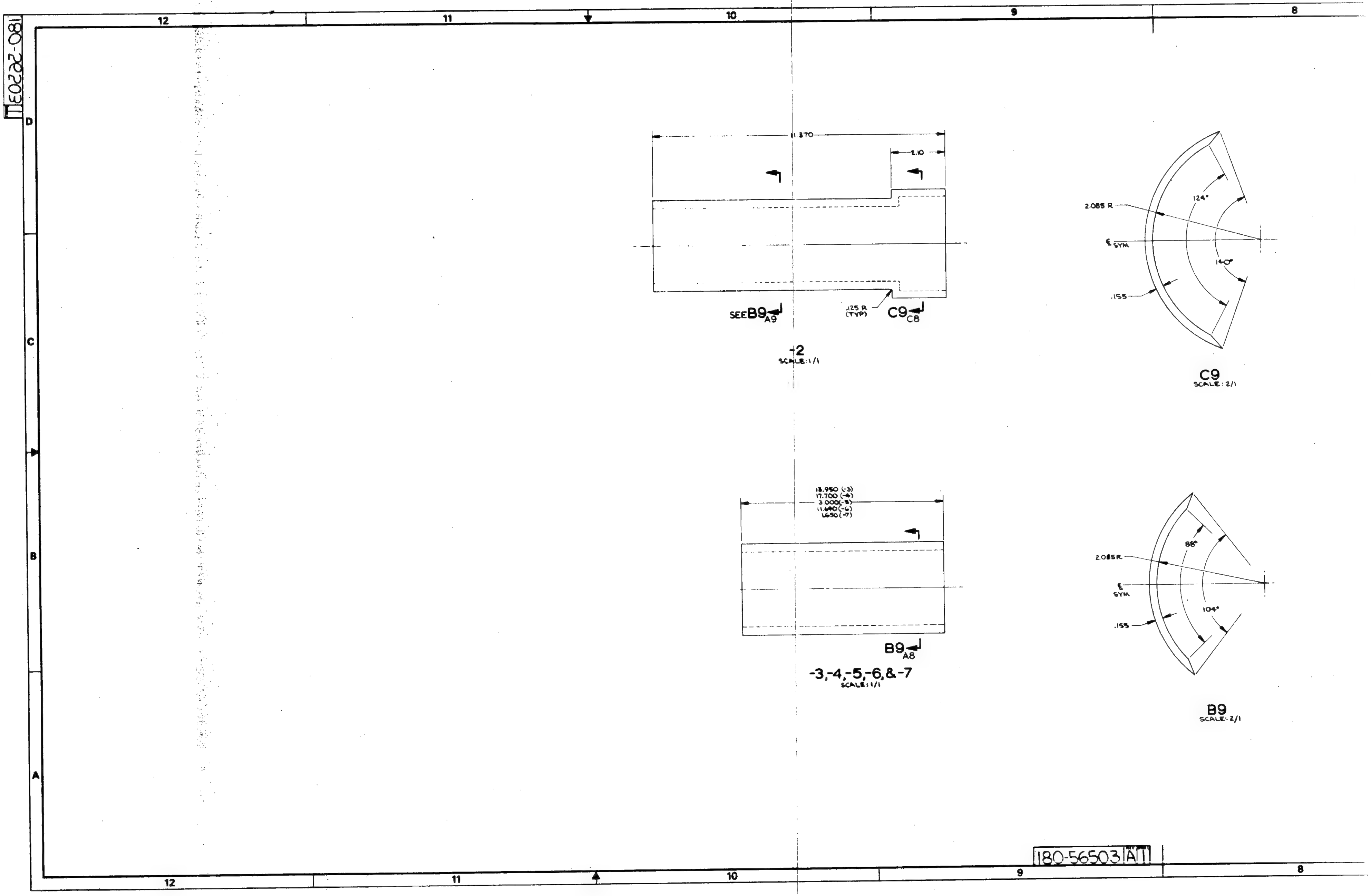
FIGURE 7-4



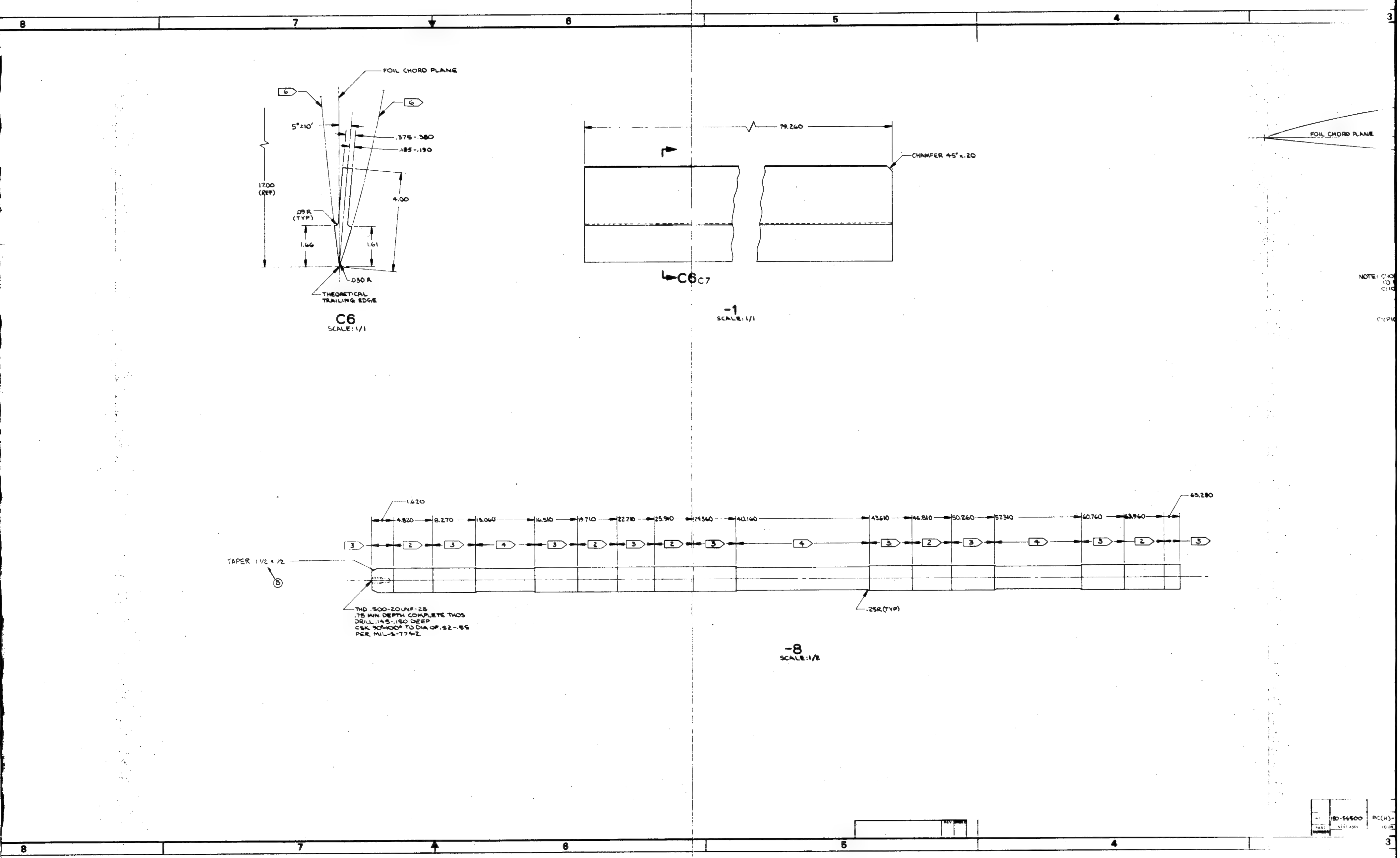
180-56502 2

180-292055


SEE C5-1 A5-1
SEE C6-1 A9-1
SEE B6-1 A8-1
B5 A6
A7
-6 (89 PLACES)
-7 (FIBER ORIENTATION TO BE ±45° TO -A-)
1B4-1
-2
LWR COVER ASSY
SCALE: 1/2
REVISIONS
SEE SHEET 1 FOR PARTS LIST AND NOTES
CONTRACT NUMBER N00024-76-C-4233
THE BOEING COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124
COVER ASSY - UPR & LWR, INBD STBD CONTROL FLAP, PC(H)-1 HYDROFOIL
J
180-56502
SH 2
180-56502
FIGURE 7-5



11.370
2.10
.125 R (TYP)
SEE B9 A9
C9 C8
-2
SCALE: 1/1
2.085 R
℄ SYM
124°
140°
.155
C9
SCALE: 2/1
13.950 (-3)
17.700 (-4)
3.000 (-5)
11.690 (-6)
1.650 (-7)
B9 A8
-3,-4,-5,-6,&-7
SCALE: 1/1
2.085R
88°
104°
B9
SCALE: 2/1
180-56503 A1


FOIL CHORD PLANE
5°±10'
.375-.380
.185-.190
17.00 (REF)
4.00
.09 R (TYP)
1.66
1.61
.030 R
THEORETICAL TRAILING EDGE
C6
SCALE: 1/1
79.260
CHAMFER 45° x .20
C6 C7
-1
SCALE: 1/1
1.620
4.820
8.270
13.060
16.510
19.710
22.710
25.910
29.360
40.160
43.610
46.810
50.260
57.340
60.760
63.960
65.280
TAPER 1 1/2 x 1/2
THD .500-20UNF-2B
.75 MIN. DEPTH COMPLETE THDS
DRILL .145-.150 DEEP
CSK 90°-100° TO DIA OF .52-.55
PER MIL-S-7742
.25R (TYP)
-8
SCALE: 1/2
FOIL CHORD PLANE
NOTE:
180-56500

NOTES

1. SPECIFICATIONS AND STANDARDS FOR THE CONTROL OF MANUFACTURING OPERATIONS (AS APPLICABLE): SURFACE ROUGHNESS SYMBOLS PER BACD 2007; PART MARKING PER BAC 5307; WELDING AND BRAZING SYMBOLS PER BACD 2002; BOLT & NUT INSTALLATION PER BAC 5009; FORM, STRAIGHTEN & FIT METAL PARTS PER BAC 5300; FINISH CODES PER DOCUMENT D0-6000; MATERIAL SUBSTITUTIONS & EQUIVALENTS PER BAC 5000; RIVET INSTALLATION & SYMBOLS PER BAC 5004
2. DIAMETER IN AREA INDICATED IS 2.0017-2.0052 INCHES.
3. DIAMETER IN AREA INDICATED IS 1.990-1.995 INCHES.
4. DIAMETER IN AREA INDICATED IS 1.850-1.875 INCHES.
5. BREAK ALL SHARP EDGES .010-.050 R (CHAMFER OPTIONAL) EXCEPT AS NOTED.
6. CONTOUR PER C3 C3.
7. GA2-4V(ELI) TITANIUM PER MIL-T-9046, TYPE III, COMP C.
8. ANODIZE PER BAC 5890 & PRIME WITH BMS 5-89 PER BAC 5514.
9. GA2-4V TITANIUM BAR PER MIL-T-9047, COMP 6

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	COMPLETELY REDRAWN	1-5-78	
B-7	B	TAPERED END OF HINGE PIN	1-25-78	

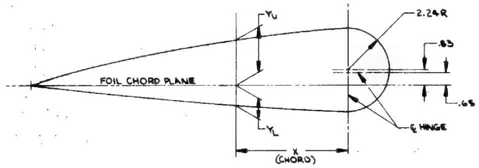
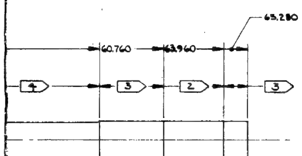


TABLE OF OFFSETS		
X±.03	Y_U±.03	Y_L±.03
0.00	3.07	1.41
3.00	2.79	1.27
6.00	2.41	1.08
9.00	1.96	0.84
12.00	1.38	0.56
15.00	0.63	0.23
17.00	0.00	0.00

NOTE: CHORDWISE SURFACE WAVINESS NOT TO EXCEED .008 INCH PER INCH OF CHORD LENGTH

C3
TYPICAL FLAP GEOMETRY



PARTS LIST

PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	CODE	MATERIAL AND SPECIFICATION	FINISH
-8	HINGE PIN	A5	2.25 x 2.25 x 65.4 (9)	
-7	DOUBLER-LEADING EDGE	A10	.155 x 4.1 x 1.8 (7)	(8)
-6	DOUBLER-LEADING EDGE	A10	.155 x 4.1 x 11.7 (7)	(8)
-5	DOUBLER-LEADING EDGE	A10	.155 x 4.1 x 3.0 (7)	(8)
-4	DOUBLER-LEADING EDGE	A10	.155 x 4.1 x 17.7 (7)	(8)
-3	DOUBLER-LEADING EDGE	A10	.155 x 4.1 x 14.0 (7)	(8)
-2	DOUBLER-LEADING EDGE	C10	.195 x 5.5 x 11.4 (7)	(8)
-1	STIFFENER-TRAILING EDGE	C5	.75 x 4.00 x 76.40 (7)	(8)

PART NUMBER	NEXT ASSY	USED ON	EFFECTIVITY
-1	180-56500	PC(H)-1	TEST ONLY

FASTENER CODES

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES: ANGLES ± 1/2°, DECIMALS .XX ± .03, DECIMALS .XXX ± .01

CONTRACT NO. N00024-76-C-4233

THE BOEING COMPANY — SEATTLE, WASHINGTON

MACHINE DETAILS - INBD STBD CONTROL FLAP, PC(H)-1 HYDROFOIL

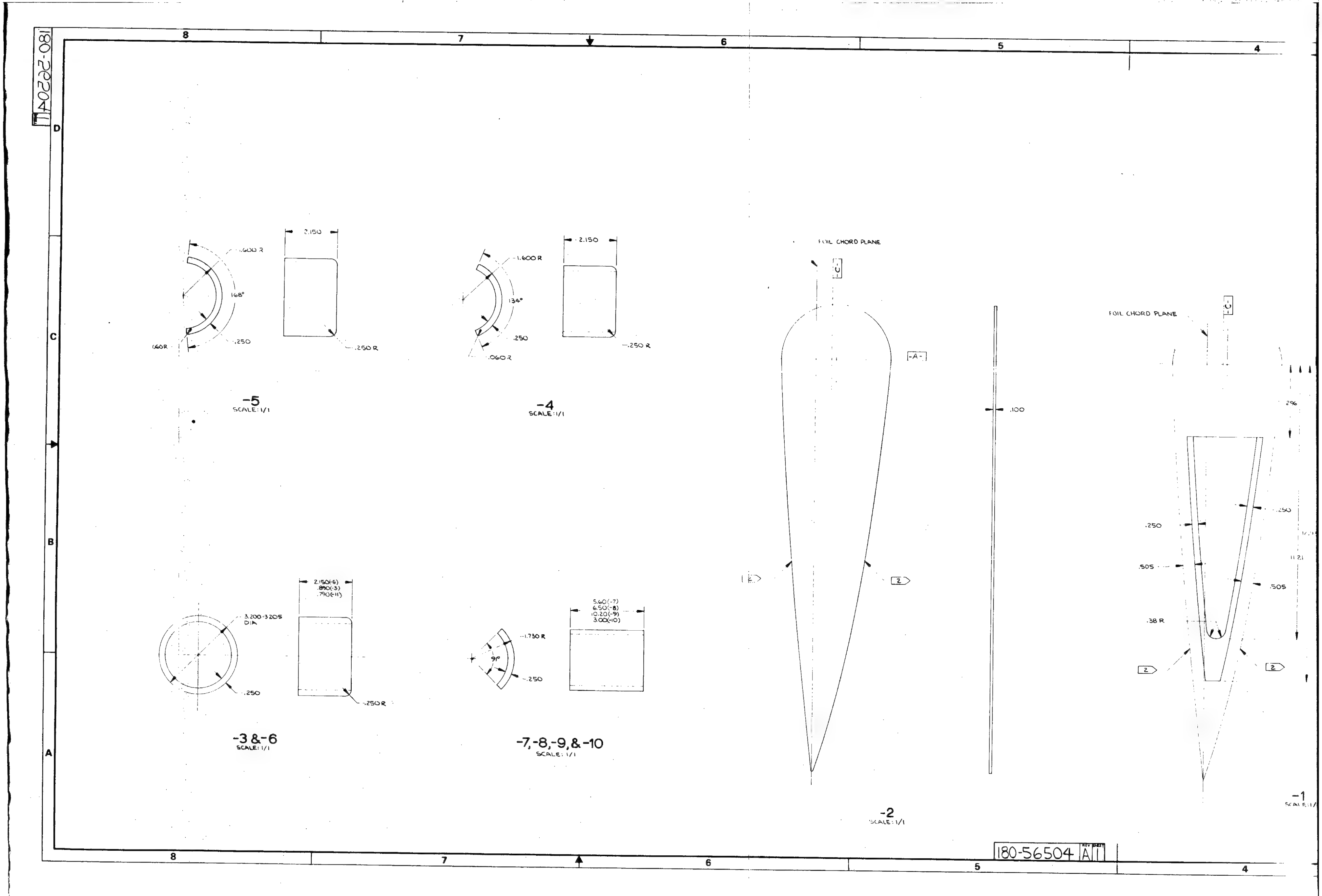
J 180-56503

FIGURE 7-6

180-56503 B

DO 6000 1312 180-22203

80
D321-51319-1



-5
SCALE: 1/1
-4
SCALE: 1/1
-3 &-6
SCALE: 1/1
-7,-8,-9,&-10
SCALE: 1/1
-2
SCALE: 1/1
-1
FOIL CHORD PLANE
2.150
1.600 R
168°
.250
.060 R
.250 R
134°
3.200-3.205 DIA
2.150(-6)
.890(-3)
.790(-11)
1.730 R
91°
5.60(-7)
6.50(-8)
10.20(-9)
3.00(-10)
.100
.505
.38 R
296
180-56504
A

REV STATUS	
SH	LTR

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	COMPLETELY REDRAWN	1/11/78	

NOTES

1 SPECIFICATIONS AND STANDARDS FOR THE CONTROL OF MANUFACTURING OPERATIONS (AS APPLICABLE)
FORM, STRAIGHTEN & FIT METAL PARTS PER BAC 5300
RIVET INSTALLATION & SYMBOLS PER BAC 5004
FINISH CODES PER DOCUMENT D2-5000
BOLT & NUT INSTALLATION PER BAC 5009
PART MARKING PER BAC 5307

2 CONTOUR PER C3 C3

3 6AL-4V(ELI) TITANIUM PER MIL-T-9047 COMP. 7

4 6AL-4V(ELI) TITANIUM PER MIL-T-9046, TYPE III COMP D.

5 ANODIZE PER BAC 5890 & PRIME WITH BMS 5-89 PER BAC 5514.

7. BREAK ALL SHARP EDGES .010 .030 (RADIUS OPTIONAL).

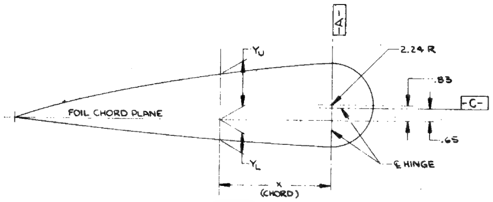
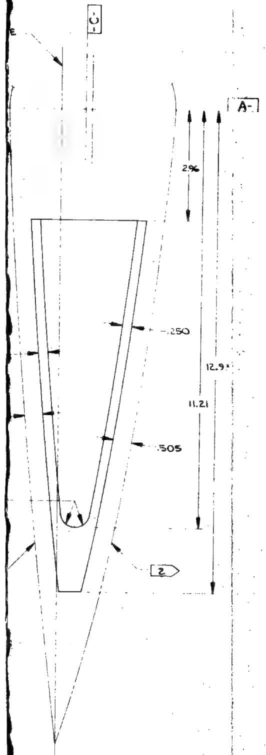


TABLE OF OFFSETS

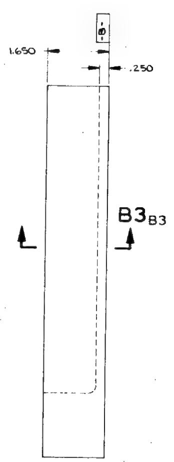
X ±.03	Y_U ±.03	Y_L ±.03
0.00	3.07	1.41
3.00	2.79	1.27
6.00	2.41	1.08
9.00	1.96	0.84
12.00	1.38	0.55
15.00	0.63	0.23
17.00	0.00	0.00

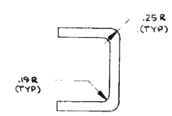
NOTE: CHORDWISE SURFACE WAVINESS NOT TO EXCEED .008 INCH PER INCH OF CHORD LENGTH.

C3
TYPICAL FLAP GEOMETRY



-1
SCALE: 1/1





B3
SCALE 1/1

PARTS LIST

QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	FIND NUMBER	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	ZONE	MATERIAL AND SPECIFICATION	CODE IDENT NO	HT TR	FINISH	PT MK	REV LTR
							-11	DOUBLER-INNER	A8	3.3 DIA x .80 3			5		
							-10	DOUBLER-INNER	A7	.250 x 2.8 x 3.0 4			5		
							-9	DOUBLER-INNER	A7	.250 x 2.8 x 10.2 4					
							-8	DOUBLER-INNER	A7	.250 x 2.8 x 6.5 4					
							-7	DOUBLER-INNER	A7	.250 x 2.8 x 5.6 4					
							-6	DOUBLER-INNER	A8	3.3 DIA x 2.20 3					
							-5	DOUBLER-INNER	C8	.250 x 2.2 x 4.7 4					
							-4	DOUBLER-INNER	C7	.250 x 2.2 x 3.8 4					
							-3	DOUBLER-INNER	A8	3.3 DIA x .90 3					
							-2	END PLATE	A5	.100 x 4.5 x 19.3 4					
							-1	CLOSURE RIB	A4	1.7 x 3.2 x 10.0 3			5		

FASTENER CODES

PART NUMBER	NEXT ASSY	USED ON	EFFECTIVITY	DWG SH NUMBER	REV LTR
-1	180-56500	PC(H)-1	TEST ONLY		

APPLICATION

DIMENSIONING & TOLERANCING PER ANSI (USASI) Y14.5
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ANGLES ± 1/2°
DECIMALS XX ± .030
DECIMALS XXX ± .010
RIVET & BOLT EDGE MARGINS ±.05
BEND RADII ± .01 ON .03 & .06
± .03 ON .09 & GREATER
SHEET METAL CORNER RADII
INT .19 .16 EXT .25 .00

REVIEW & APPROVAL
DWG QUAL
STRUCT
MATL & PRCS
CHANGE/ITEM NUMBER

CONTRACT NUMBER N00024-76-C-4233
DWN Don Good 1/11/78
CHK
ENGR
ORG
PROJECT APPROVAL

THE BOEING COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124

MACHINE DETAILS—
INBD STBD CONTROL FLAP,
PC(H)-1 HYDROFOIL

SIZE J CODE IDENT NO 180-56504
SCALE NOTED SH 1 OF 1

DWG ORIG BY (ORG)

DRAWING RECORDS CLERK

180-56504 REV A SHEET 1

FIGURE 7-7

180-22204

81

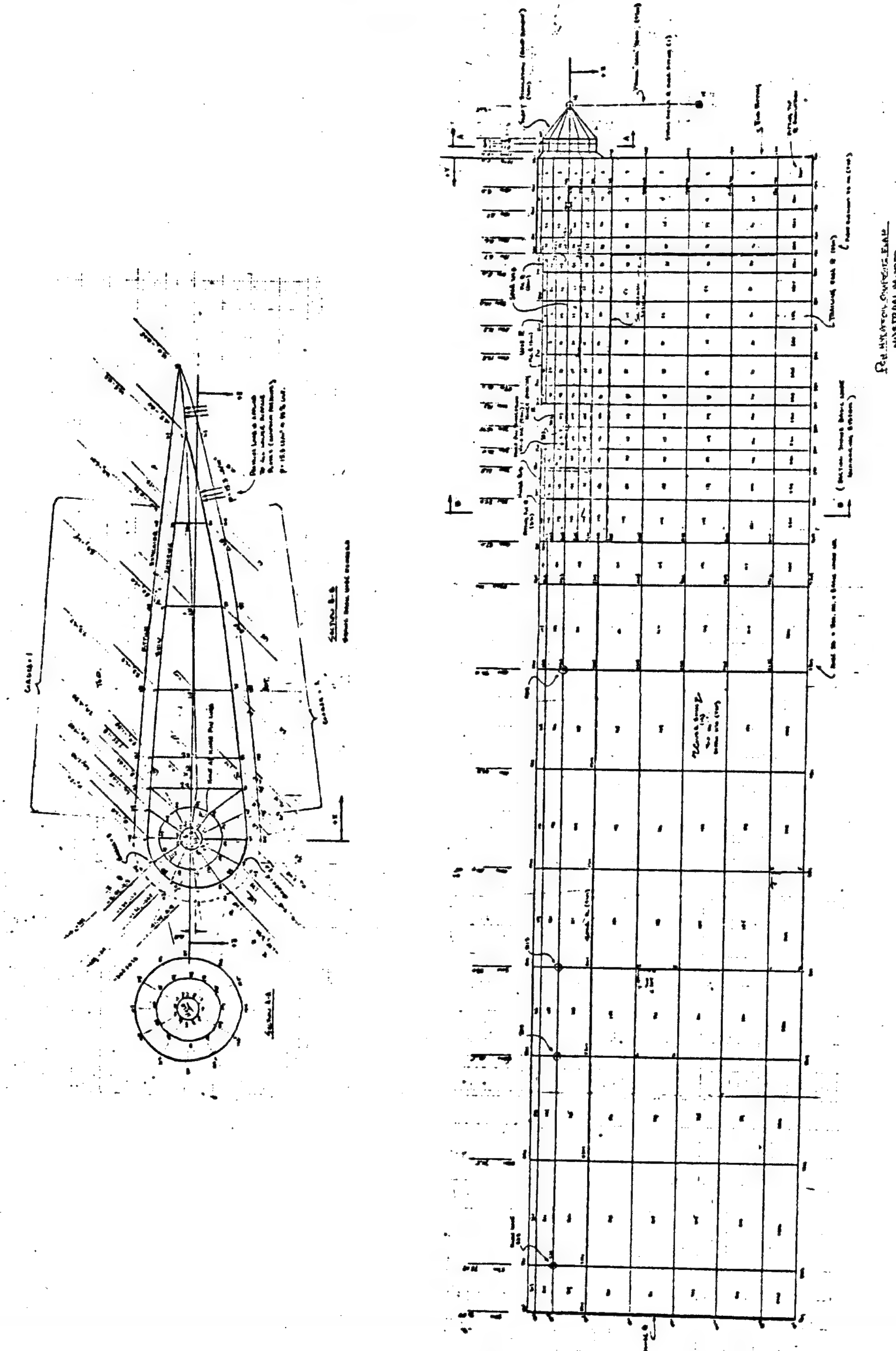


FIGURE 7-8 NASTRAN MODEL

TOP COVER SHEAR (N_{xy}) LOADS (lb/in. AT 40% ULT.)

- CORRECTED OFFSET PLATE RESULTS (RUN AF4YCXK)

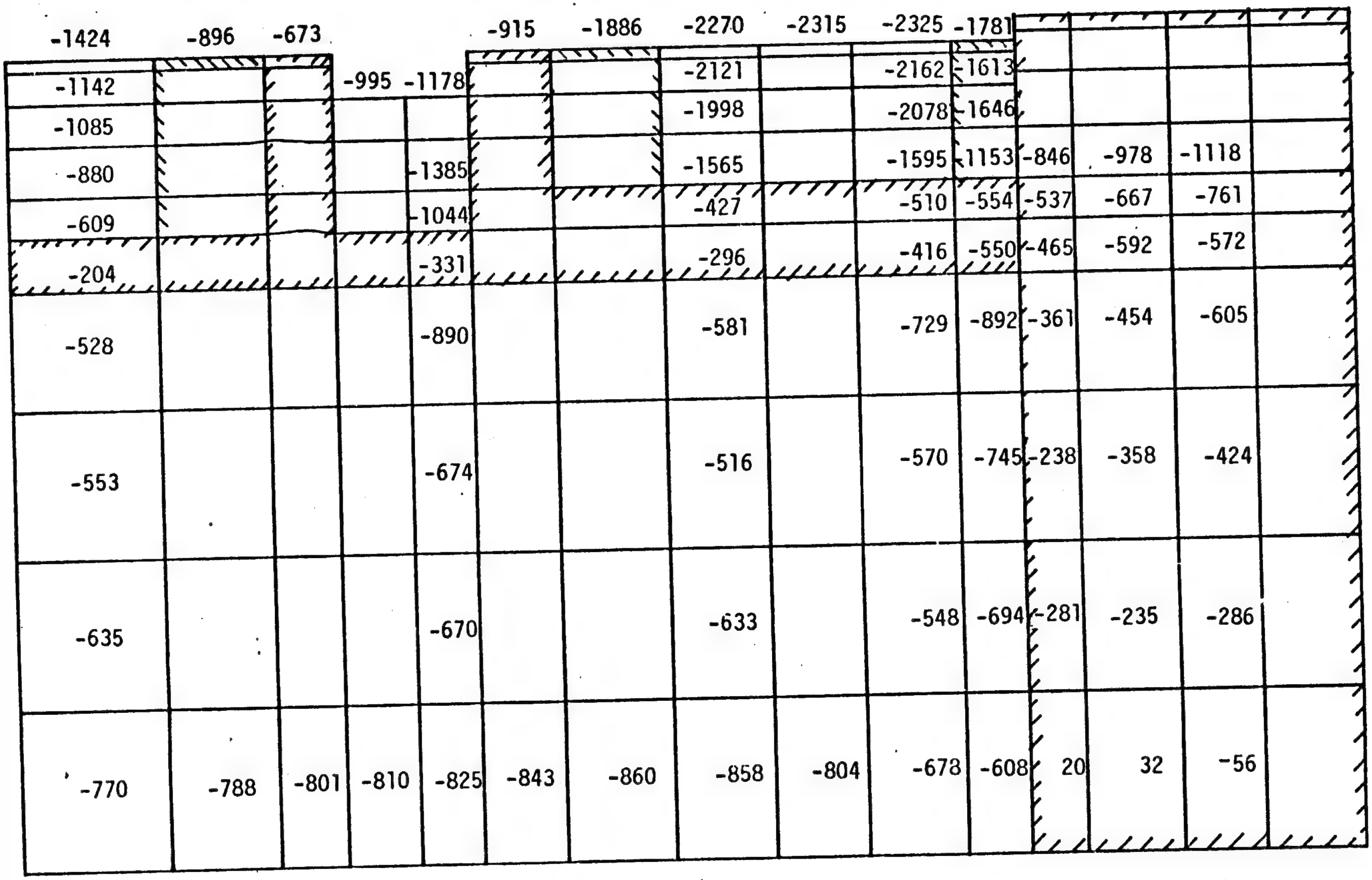


FIGURE 7-9 TOP COVER - CORRECTED SHEAR LOADS

FLAP LOADS

MAX FATIGUE CONDITION $p_{flap} = 17.5$ psi

NOTE: $= 43.8$ psi "CRITICAL"
$= 29.2$ psi "LIMIT"

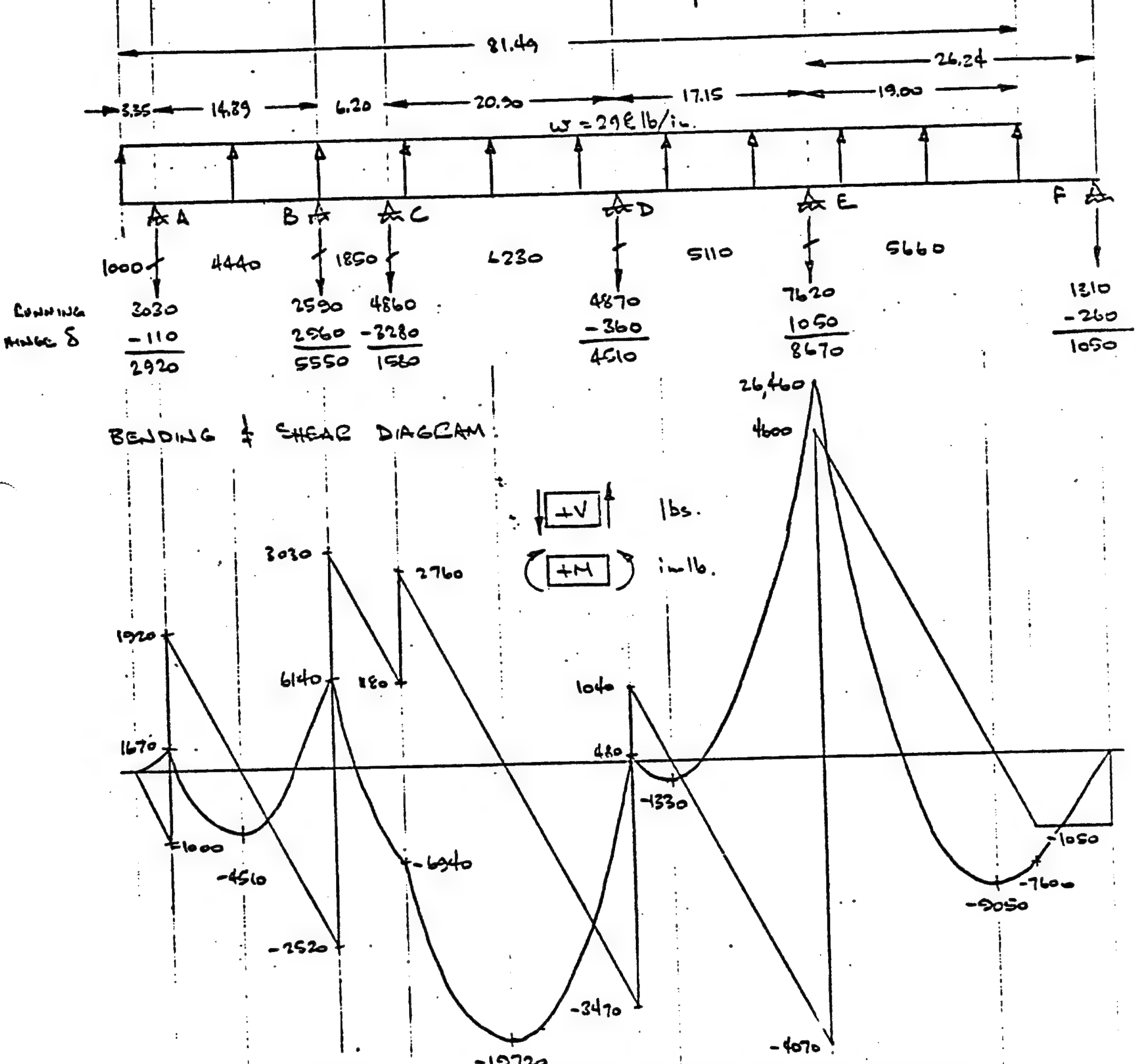


FIGURE 7-10 AFT INBOARD FLAP SHEAR AND MOMENT DIAGRAM

TORQUE DIAGRAM.

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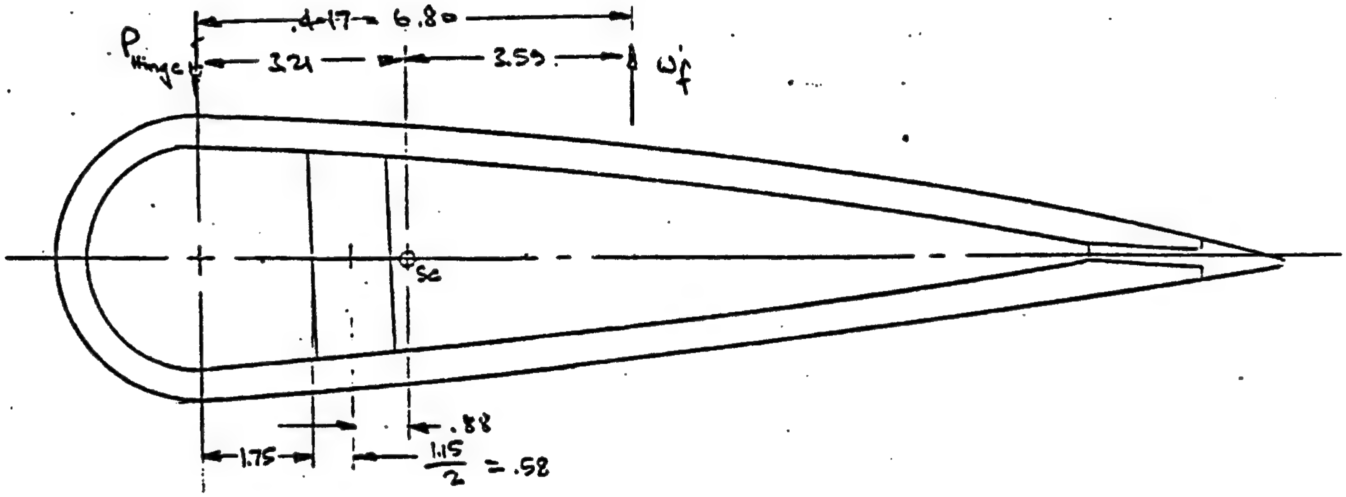
CONSERVATIVELY USE SHEAR CENTER FOR SINGLE CELL

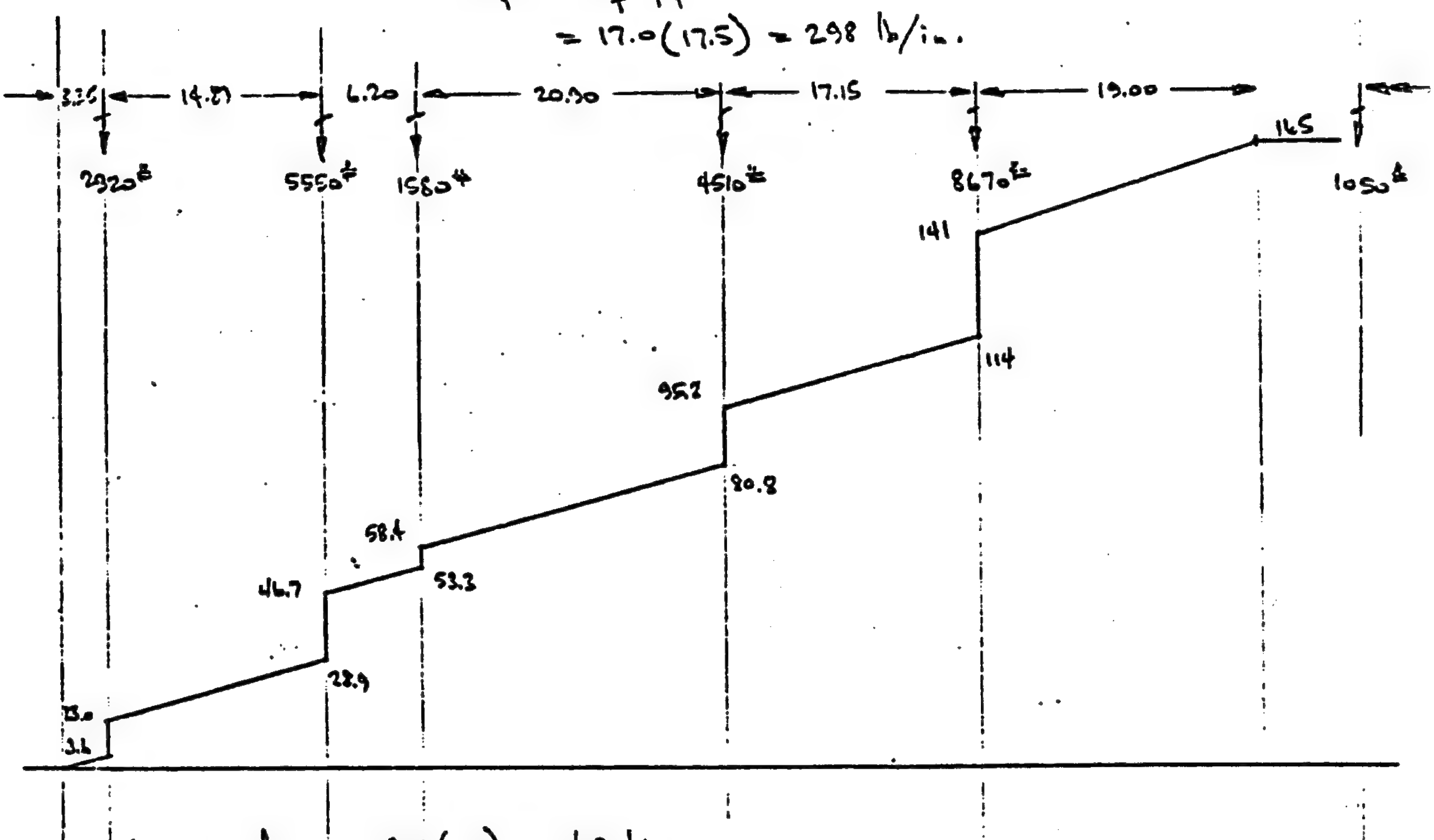


MAX FATIGUE COND.

$p_f = 17.5$ psi

NOTE $p_f = 29.2$ psi - lim
$= 43.8$ psi - crit.

$\omega_f' = c_f \, p_f$
$= 17.0(17.5) = 298$ lb/in.



$L_{flap} = l_f \, \omega_f = 81.5(298) = 24.3$ kips

$M_{crank} = l_f \, \omega_f \cdot 6.80 = 81.5(298)(6.80) = 165$ in-k

FIGURE 7-11 COMPOSITE FLAP TORQUE DIAGRAM

TABLE 7-1

FATIGUE LOADS SPECTRUM

$p_{crit} = 1.5\ p_{limit} = 6300\ psf = 43.75\ psi$

n cy/hr	$\frac{p_{max}}{p_{crit}}$	$\frac{p_{min}}{p_{crit}}$
544	.30	.10
312	.35	.10
137	.40	.10
$\frac{7}{1000}$	.40	-.20

TABLE 7-2

FATIGUE LIFE SUMMARIES

Item	$N_{.95/1.0}$ Life hours [1]
Hinge Lug	>100,000
L.E. Bulkhead Shell at Hinge Lug -Fastener Holes	15,000
Closure Rib - Aft Bay Fastener Holes	26,000
Closure Rib Shoulder Fillet	63,000
L.E. Bulkhead Shell at Closure Rib	9,000
Crank Arm Neck	12,000
Crank Arm Hinge Stub Radius	>100,000
Crank Arm Drive Lugs	[2]
Lug Hole	5,700
Base Of Clevis	2,000

[1] Foilborne Operating Hours

[2] Fatigue Test Flap will be beefed-up to increase life

8.0 COMPOSITE FLAP FABRICATION

A full-scale component has been fabricated using the techniques developed during the fabrication of the feasibility component. Titanium billets were cut to the approximate shape of the crank and spar details with a plasma torch. These parts were then sandblasted and chem-milled to remove the oxidized surface and then rough machined to their approximate final configuration. The crank was then rotated 12 degrees relative to the integral closure rib by hot forming. The crank and two spar details were then electron beam welded into a single assembly. This part was then sent to the machine shop for milling and boring to its final configuration. The nose plates were chip formed on a break, thermally sized using ceramic dies, and then machined to their final geometry. The remaining titanium details, the trailing edge, closure rib and inserts were made using conventional milling and turning methods. Figure 8-1 shows all of the completed titanium details.

The covers were made by laying up 36 plies of .013 T300/934 graphite cloth at ±45 degrees on a contoured layup tool. This layup was debulked every five plies with one type 181 fiberglass bleeder for each two plies. Debulking was performed at 120°F and vacuum pressure. A peel ply was placed at both sides of the laminate. The parts were then cured at 350°F and 100 psi in an autoclave.

The covers were then locked in a holding fixture and trimmed. They were machined to their final configuration on a BOKO pattern mill. After trimming, holes were drilled in the lower cover to accept titanium inserts at the bolt locations. The stepped titanium inserts were then bonded in place with a room temperature curing adhesive. Figure 8-2 shows one of the completed covers.

Cladding made of 10 mils 6Al-4V titanium was prepared for bonding to the surfaces of the cover laminates. The titanium skins were cleaned, anodized, and primed with an epoxy coating. They were then bonded to the covers using EA9628 (Hysol) at 250°F and 100 psi.

The flap detail parts were assembled and held together with a holding fixture. This assembly was then placed on a milling machine and through-bolted holes were line drilled. Initially, an end mill tool was used to establish a flat in the upper cover. A tap size through hole was then drilled. The bottom cover was removed and tapped. The top cover and spar were drilled up to bolt body size. The upper cover was countersunk to accept the high torque bolt head.

To assure of a total contact fit between the covers and the substructure, a prefit was performed prior to final assembly. This was accomplished by placing a foam adhesive between FEP parting film at all bonding interfaces. The resulting assembly was bagged and processed through the adhesive cure cycle. After cure, the adhesive thicknesses were measured to determine the number of plies of adhesive required at the various locations during final assembly. It was determined that a maximum number of two plies of 10 mil adhesive were required at only a few select areas.

All metal parts were then cleaned and anodized in preparation for bonding. The crank/spar assembly was shot peened on all surfaces prior to this preparation.

Prior to final assembly, the covers were instrumented with 52 strain gages and one water detection channel on their inner surfaces to provide data during subsequent calibration tests and sea trial evaluations. This instrumentation was installed with 50 foot leads which were routed through a 3/4 inch diameter hole passing through the crank stub.

The composite flap details were stacked for final assembly. Hysol 9628 film adhesive was placed at the bond interface surfaces and the assembly was then bolted with titanium fasteners. It was bagged, placed in an autoclave and processed through an adhesive cure cycle of 250°F for 90 minutes and 50 psi. The assembly was then removed from the autoclave and visually inspected. All bond joints were closely joined and indicated excellent adhesive flow. The bolts were retorqued to their required levels and the

closure rib was installed. The bolt heads in the countersunk holes were primed and fairing compound installed, troweled smooth and cured to complete the assembly. Figure 8-4 shows the completed composite flap.

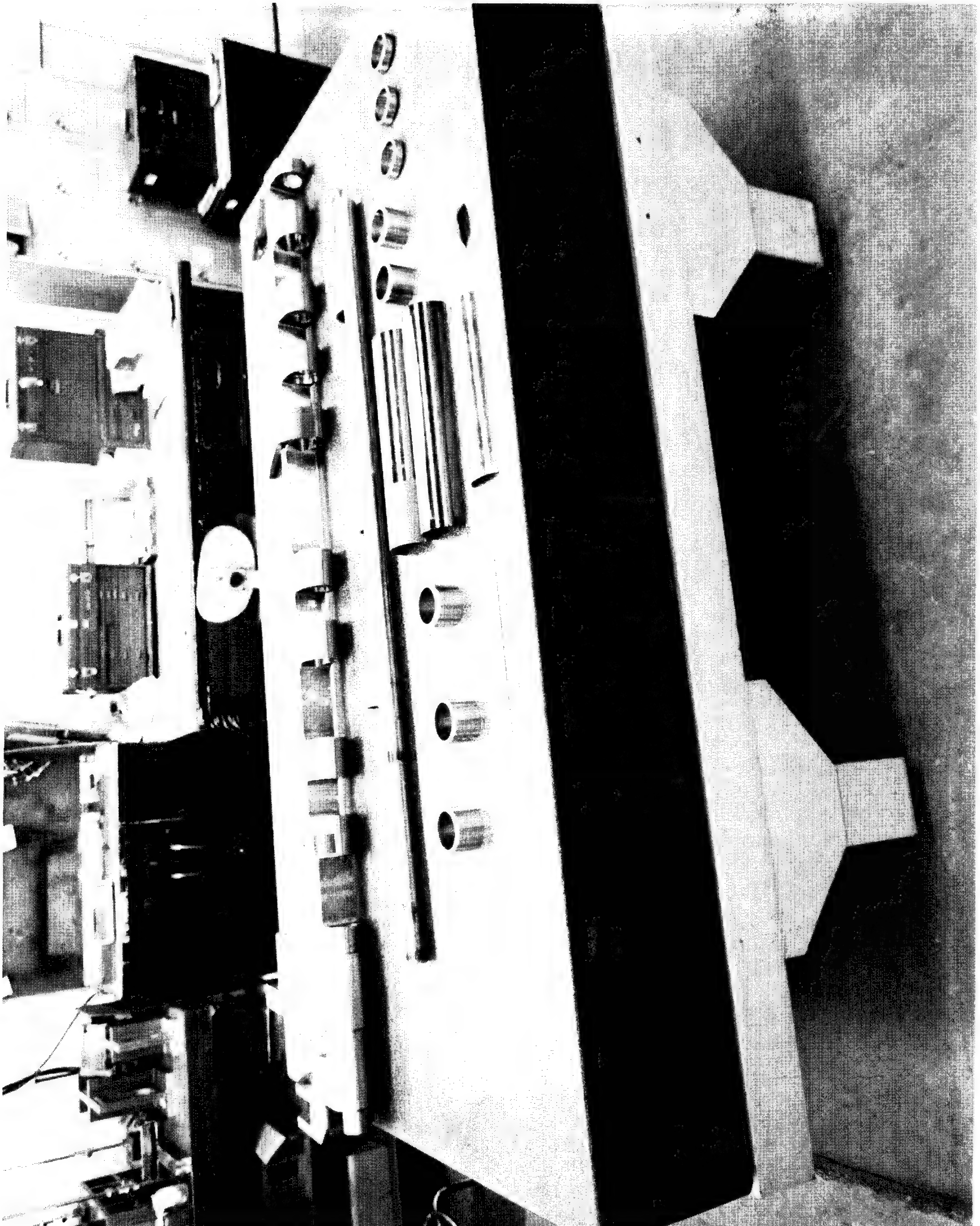


FIGURE [illegible] COMPLETED [illegible]

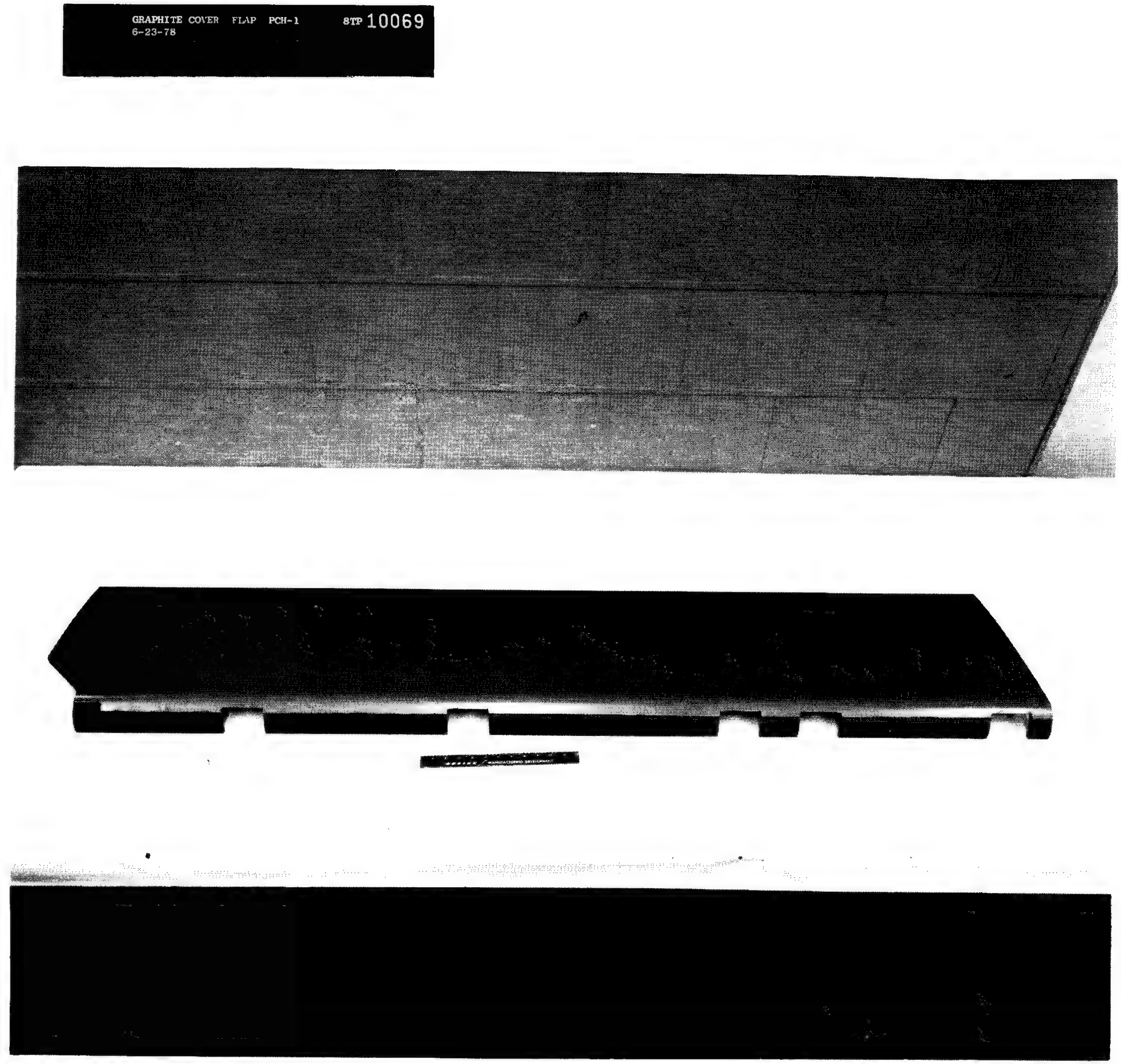


FIGURE 8-2 COMPLETED COMPOSITE FLAP COVER

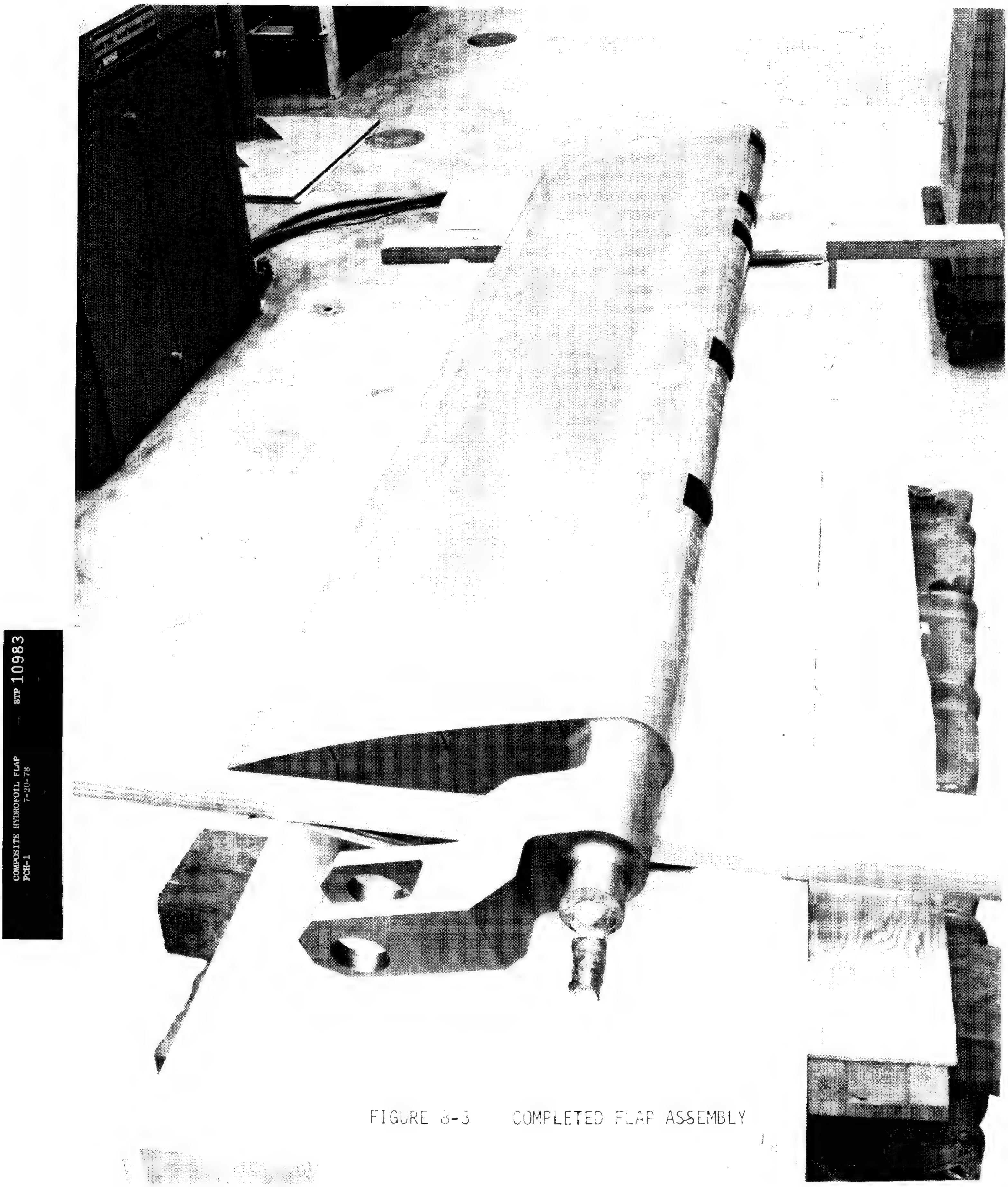


FIGURE 6-3 COMPLETED FLAP ASSEMBLY

9.0 CALIBRATION TEST

The advanced composite hydrofoil flap was instrumented with 52 strain gages and calibrated to determine gage outputs as a function of applied load.

Prior to final assembly, a total of 52 strain gage channels were applied to the interior surfaces of the upper and lower flap covers at locations indicated in Figure 9-1. The strain gage lead wires were routed through the crank bearing stub shaft and sealed during the final assembly operation. Figure 9-2 shows a photo of the strain gage installations on a flap cover prior to final assembly.

The calibration was accomplished in the 90 and 120 inch test frames in the Material and Structures Test Laboratory. Test fixtures were fabricated and installed in the test frames with the flap hinge blocks bolted down to the base plates of the test frames. A 23 kip hydraulic actuator was attached to the flap crank arm through a spherical ball bushing at a 25 degree angle to the hinge line and its other end mounted to a beam assembly attached to the test frame columns. A load reaction beam with a 2 inch thick foam rubber pad, 5 inches wide and the length of the flap, was also mounted by a spherical ball bushing to the test frame columns. The reaction beam was positioned sequentially at six positions around the flap to provide a uniform reaction pressure of up to 20 psi. Sketches of the test set up are shown in Figure 9-3.

Figure 9-4 is a photo of the flap prior to installation, with the hinge pin bearing blocks installed. Photos of the flap in the test fixture with the load reaction beam at loading strip #2 are shown in Figures 9-5 and 9-6.

The strain gage leads were connected to Consolidated Systems Corporation bridge completion networks, using a three wire hookup with shunt cal resistors. Outputs of the strain gage bridges were recorded on magnetic tape by NLS digital data system. Applied load was sensed by a 20 kip load cell attached to the loading actuator, and recorded on the magnet tape along with

the strain gage outputs. Magnetic tape data was processed by SDS 910 data system and outputed in tabular form.

Calibration loads were applied by a servo controlled Miller hydraulic actuator in conjunction with a Shore Western servo controller, using manual set point programming. A Fluke D.V.M. provided a visual display of the applied load for the controller operator.

Loads were applied to the flap crank to produce a maximum reaction pressure of 20 psi over the 5 inch wide foam rubber pad. The reaction beam was first located at one of six load strip areas on the flap. Load was increased in 10 percent increments until the maximum reaction pressure of 20 psi had been attained, and then the pressurewas returned to zero. The strain data was recorded at each increment and if data differed from previous zero loading by more than 10 percent, the load sequencing was repeated. If data proved to be repeatable, the reaction beam was moved to the next load strip area and the loading process was repeated. This was continued until strain gage data was attained after loading all six load strip areas. The reaction beam was then returned to the initial load strip area and incremental loading was repeated. The data obtained from this set of loadings matched the initial data well within the required 10 percent tolerance. The calibration test was therefore terminated.

In general, all data obtained from gages with a significant output was repeatable within the required 10 percent tolerance. A few gages with very low outputs and within the noise area of the data system exceeded the 10 percent limit. These were not monitored as a basis for repeat or advance decisions.

Calibration data was obtained for each strain gage at each load increment applied to several load strip areas (#1was repeated). This data was tabulated in units of millivolts to the fifth place (0.xxxxx MV). The maximum resolution of the data system was ±.010 MV and digits beyond the hundredths place were ignored. The gages with outputs above this level were repeatable well

within the acceptable ±10 percent tolerance. The quantity of data was quite extensive and completely filled 151 data pages. These data have been delivered to the Navy as a separate deliverable item. This data was transmitted by Data Transmittal Form dated 29 August 1978.

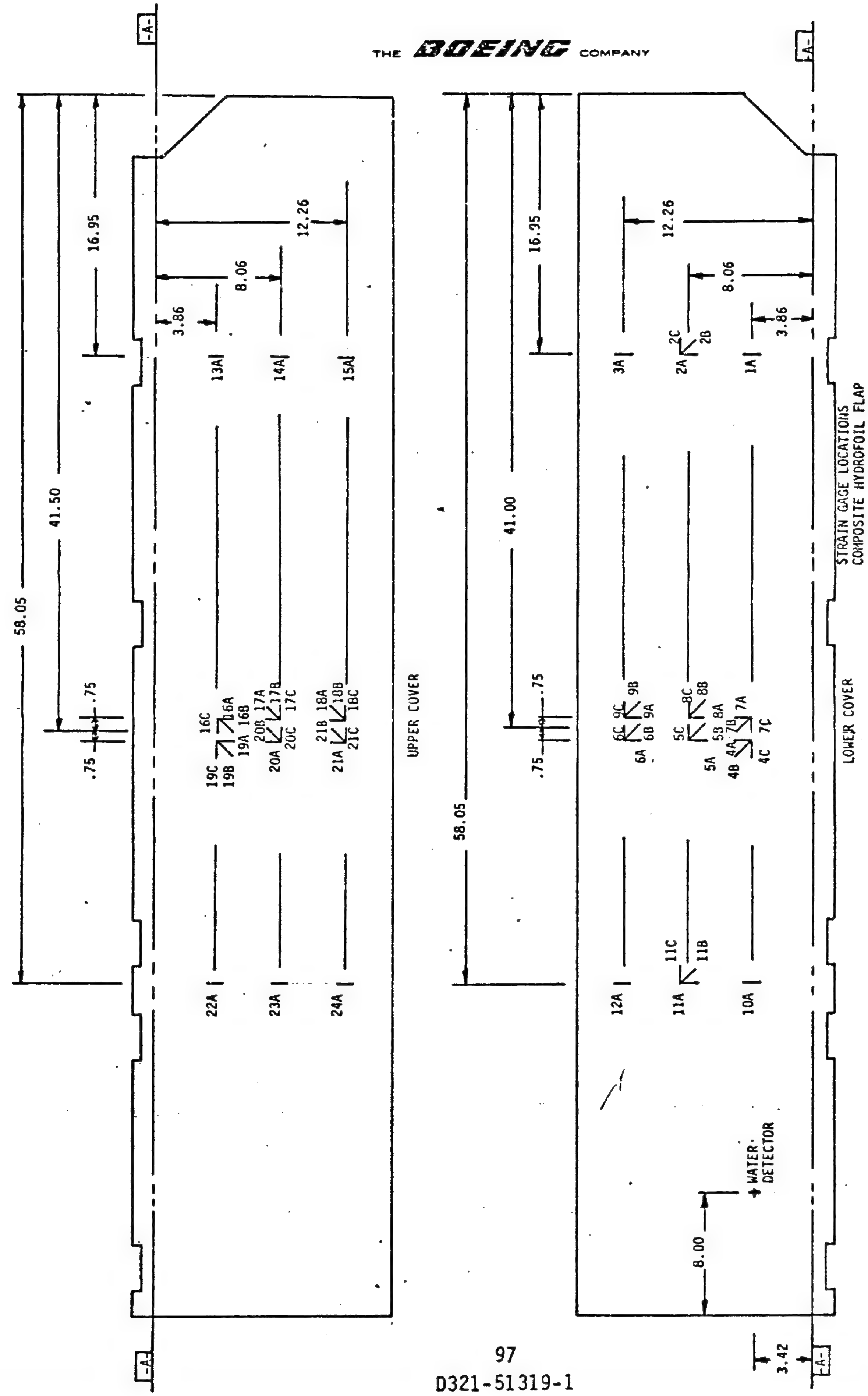


FIGURE 9-1 COVER STRAIN GAGE LOCATIONS

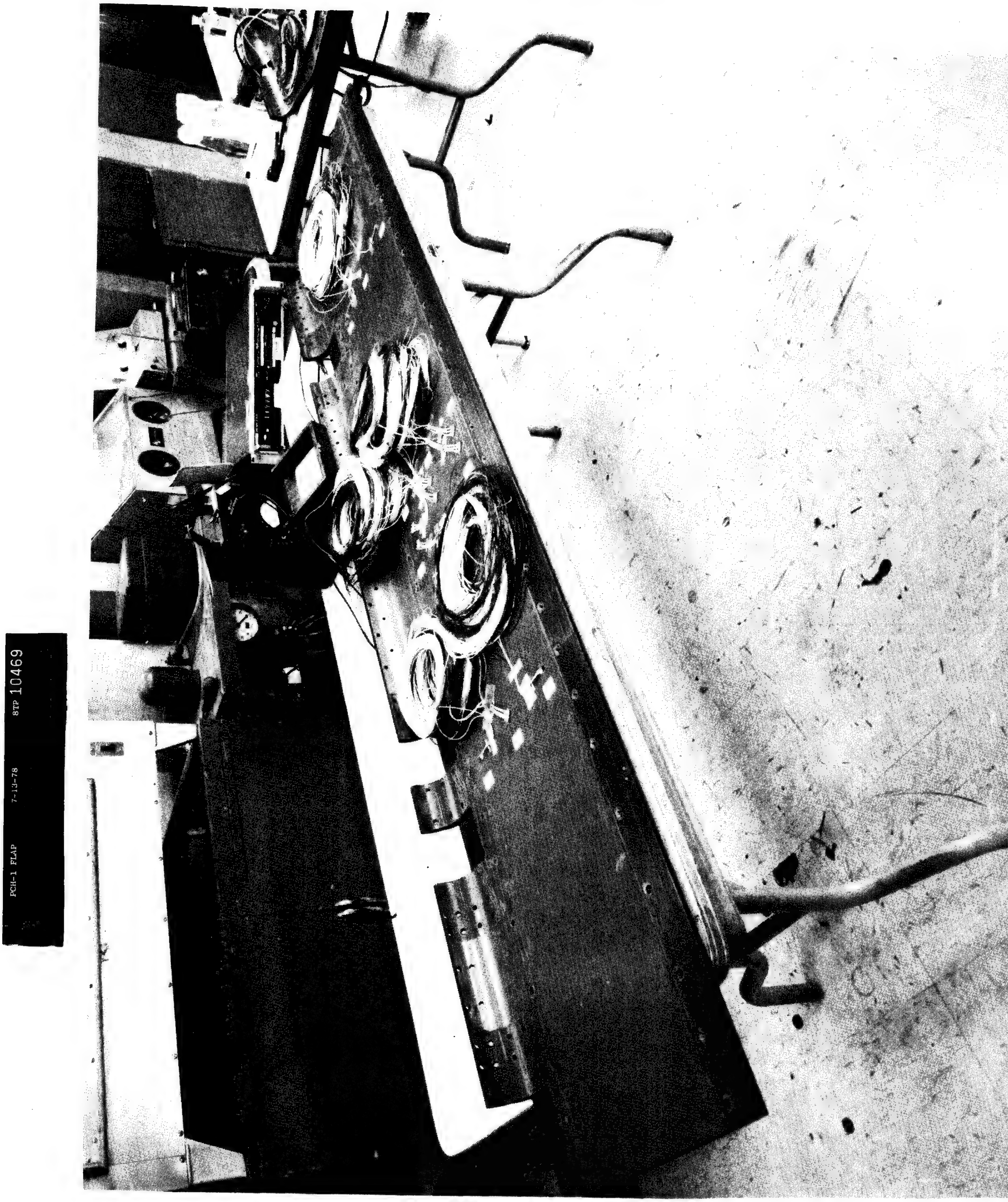


FIGURE 9-2 STRAIN GAGE INSTALLATIONS ON COMPOSITE COVER

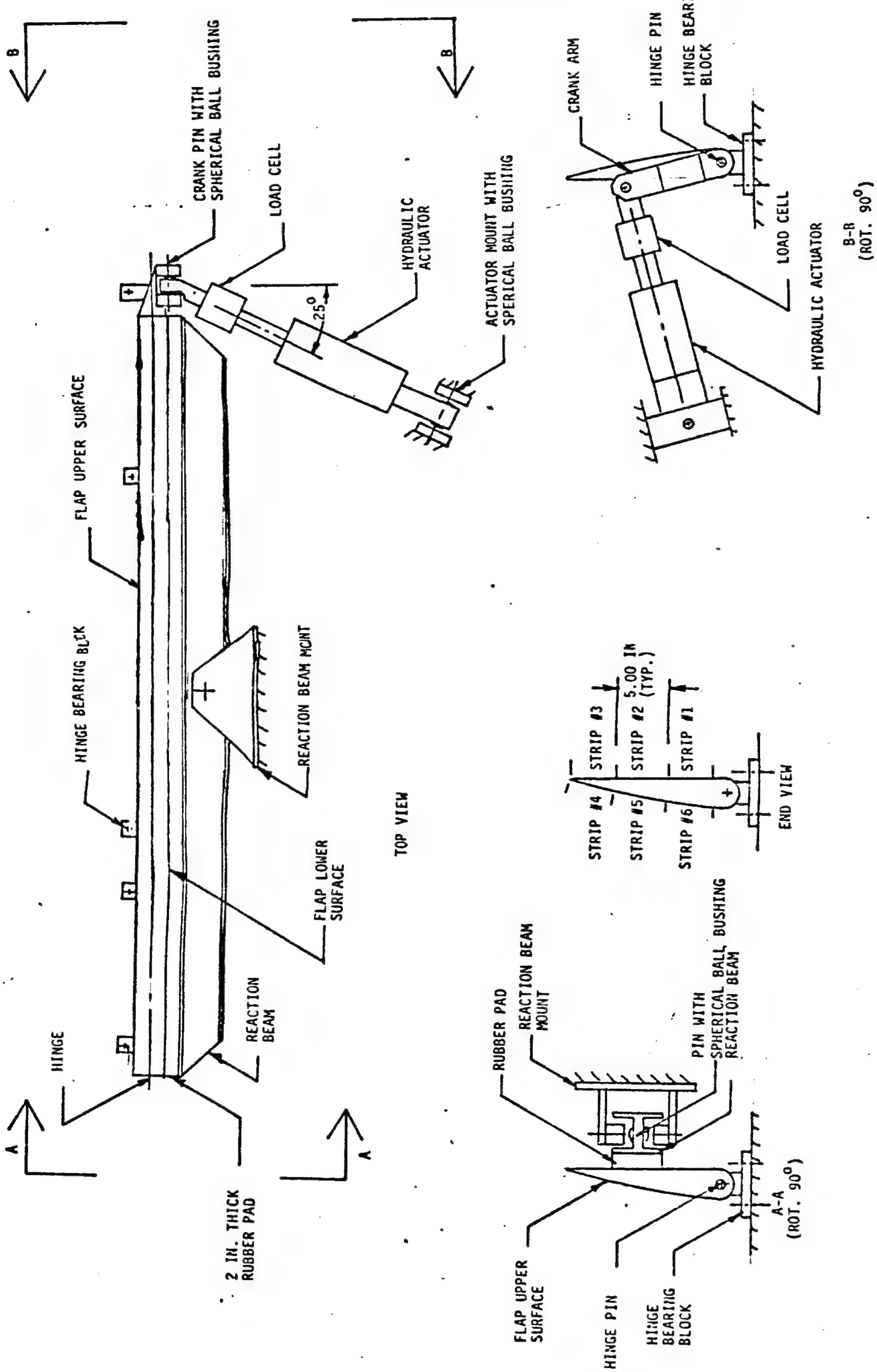
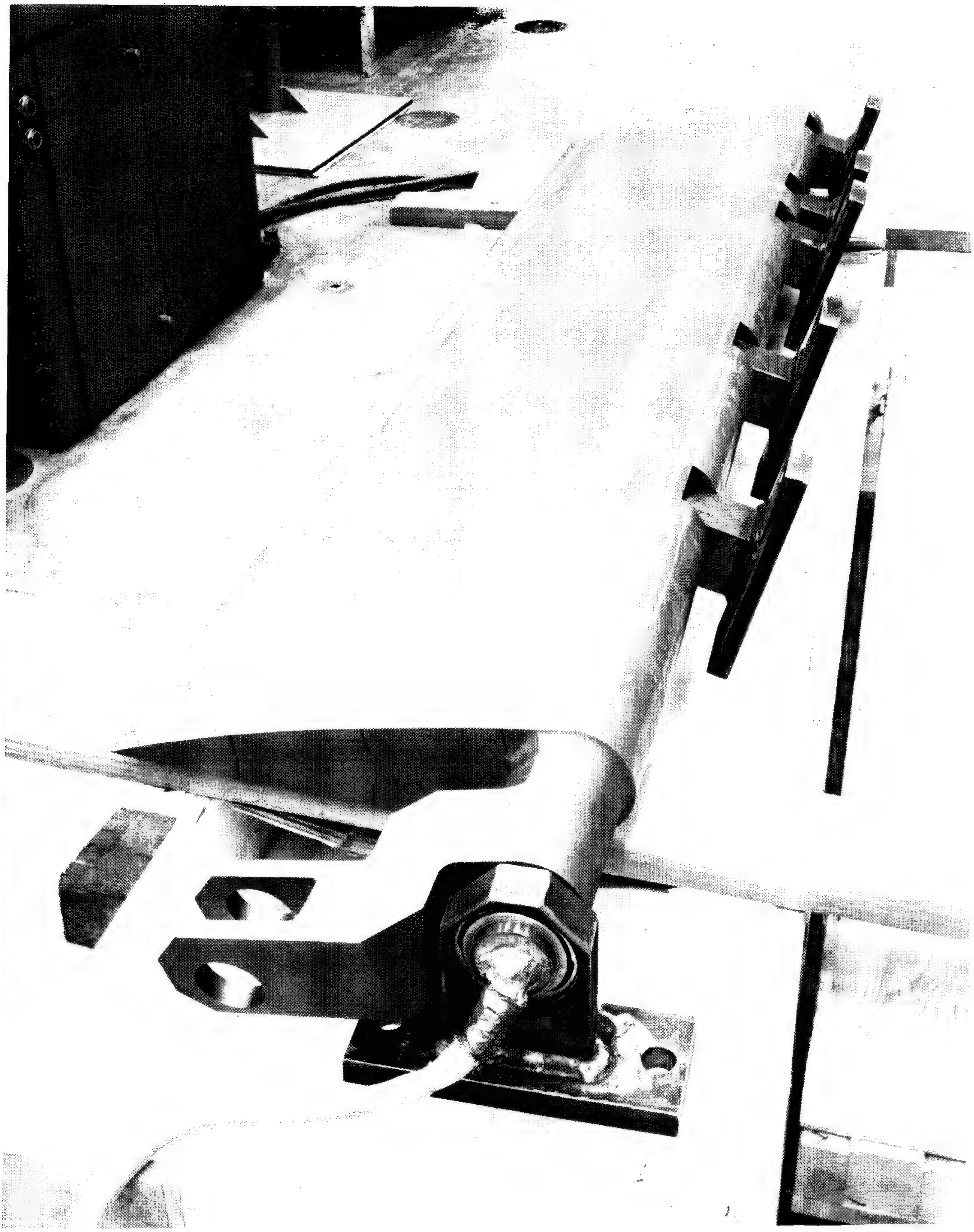
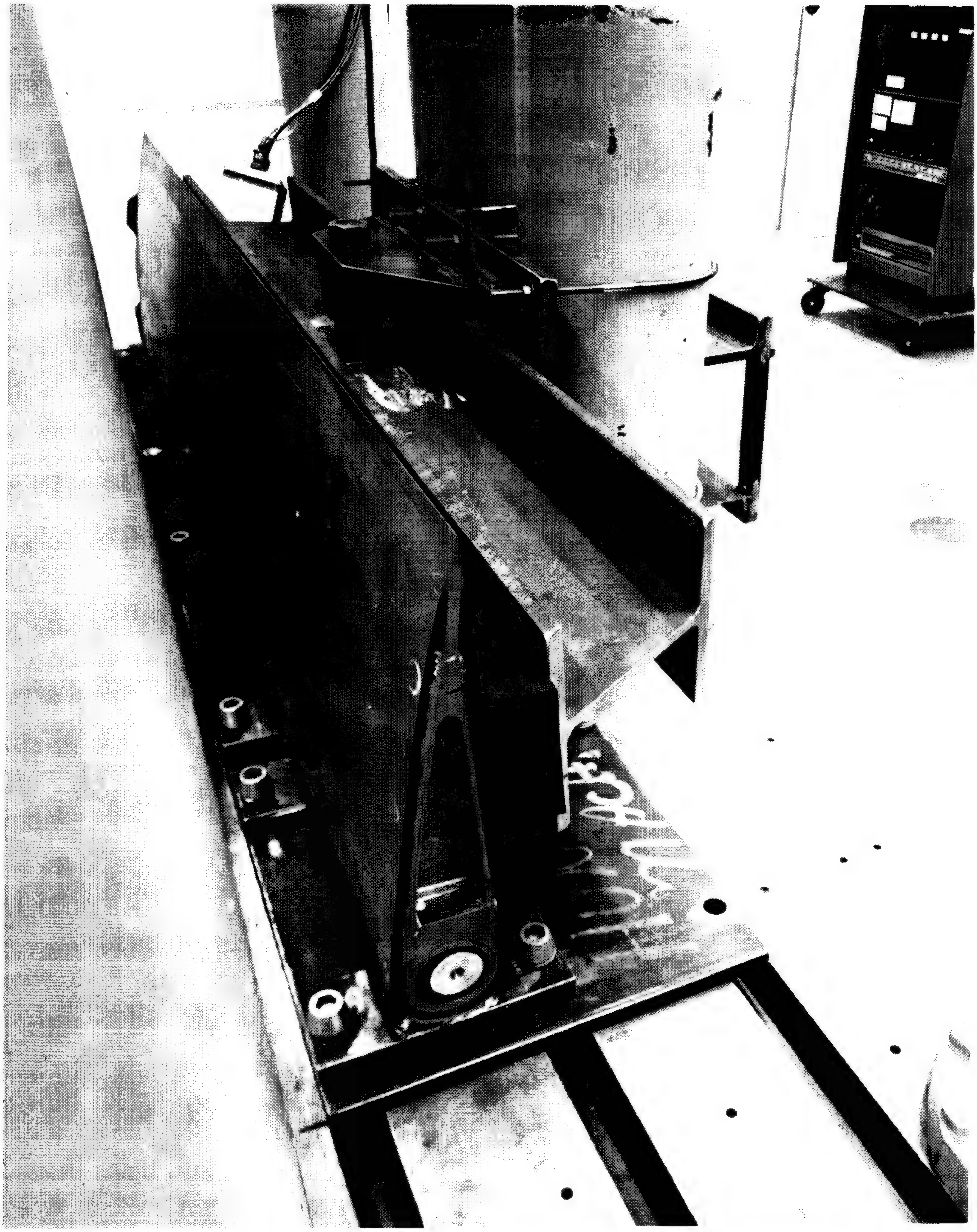


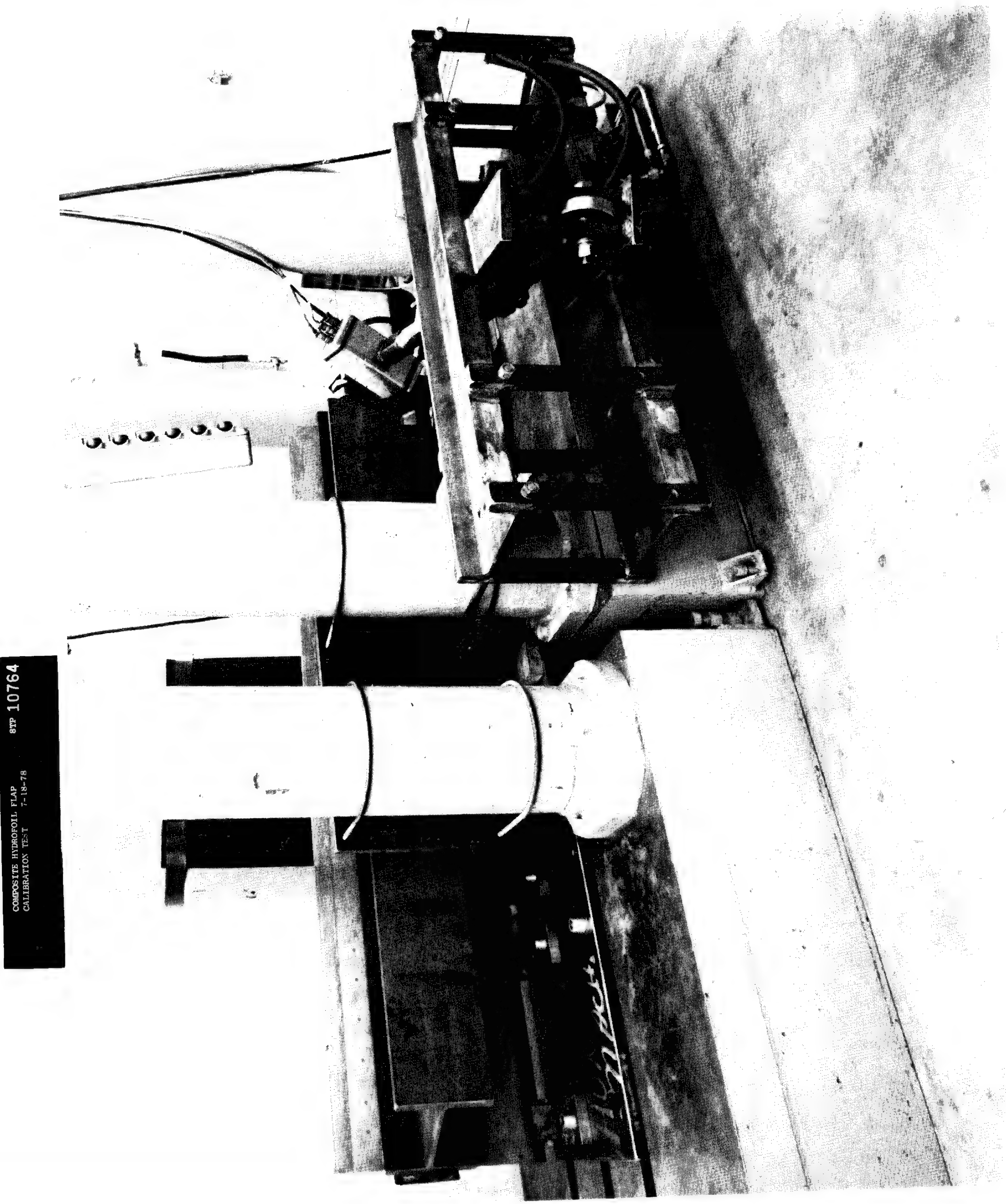
FIGURE 9-3 TEST SETUP - SKETCH 1



FIGURE



COMPOSITE HYDROFOIL FLAP CALIBRATION TEST 7-18-78 8TP 10766


COMPOSITE HYDROFOIL FLAP
CALIBRATION TEST 7-18-78
8TP 10764

10.0 FLAP INSTALLATION

The advanced composite flap has been installed on the PCH-1 hydrofoil for a full series of instrumented trials. The trials will be used to demonstrate the ability of the composite to withstand the hydrofoil environment and to obtain service loads information. This evaluation will last approximately one year to permit the flap to encounter a full spectrum of sea state conditions. After the trials have been completed, the flap will be removed and tested in fatigue by DTNSRDC to demonstrate its ability to attain design life goals.

To initiate the composite flap installation, the existing steel flap was removed from the PCH-1. It was sent to the laboratory to be examined and measured. The bearing blocks were bolted to a base plate prior to their removal from the steel flap. The retaining bolts were removed, which released the blocks from the steel flap. The continuous titanium pin designed to be used with the composite flap was then inserted in the bearing blocks to insure that the hinge line was within tolerance for both flaps. The hinge pin was inserted without difficulty. After testing the alignment, the hinge pin was removed and the hinge blocks were inserted in the composite flap. Fabroid spacers were machined and inserted adjacent to the bearing block closest to the crank to ensure that it was at its proper location along the length of the hinge line. Spacers were not used with the remaining four bearing blocks, which permitted them to float along the hinge line and minimize interface tolerance problems with the foil. The hinge pin was inserted and then locked in place with a bolt through the covers and the end closure plate was bonded and bolted in place to complete the assembly. In addition to installing the hinge bearings, the crank pedestal bearing was installed in the laboratory. The crank on the composite flap had a larger pedestal shaft than the steel flap. A special bearing was purchased to fit on the larger shaft and still fit within the existing steel housing on the boat. This bearing was installed without difficulty. Figure 10-1 shows a photo of the composite flap with the bearing blocks and the crank pedestal bearing installed. The steel flap can be seen in the background

in this photo.

The composite flap-bearing assembly was then shipped to the Bremerton Naval Ship Yard to be installed on the PCH-1. Some grinding was required on the aft portion of the foil to provide clearance for the flap. The composite flap was placed in position and the bearing blocks were bolted to the foil. While attempting to hook-up the crank to the control linkage, an interference problem was encountered. This required grinding on both the crank and the linkage. After grinding a larger radius in the clevis of the crank, this area was polished and shot peened with a rotopeen. The crank pin was then installed without further difficulty.

A second interference problem was encountered between a corner on the crank and the fiberglass housing. This problem was reviewed, and it was concluded that this portion of the crank could be ground to fit without weakening the assembly. The strain gages were hooked-up to the ship's data system to complete the flap installation. The wires were covered with a metal shielding and a stress loop was formed as they emitted from the crank stub. They were then routed up through the strut and connected to the data system. Also, a small section of cladding, approximately ½ inch x 2 inches, was delaminated at the inboard bearing cutout during the flap installation. The delmaination geometry was established using ultrasonic equipment. The bond was repaired using liquified epoxy adhesive. In addition, formed 10 mil titanium clips will be bonded at all the bearing cutouts to cover the exposed bond lines.

FIGURE 10-1 COMPOSITE FLAP WITH BEARING HOUSINGS INSTALLED

11.0 NONDESTRUCTIVE EVALUATION (NDE)

A study was performed to determine the most feasible techniques for inspecting the titanium clad composite covers used in the composite flap design. A test panel was fabricated incorporating the same concept as the covers. It included a 36 ply graphite/epoxy fabric laminate with 10 mil thick 6Al-4V titanium cladding bonded to its surfaces. The test panel contained twelve areas in which artificial flaws were fabricated. It was inspected by several different procedures to determine their capability to detect these known defects.

The defects that were built into the test panel were either in the bone line between the titanium cladding and the laminate, or as holes in the laminate. The defects included bond inclusions of Teflon, Kapton and a parting agent, adhesive voids, and drilled holes in the laminate of various diameters and depths. A detailed description of the fabricated flaws is shown in Figure 11-1.

Through transmission ultrasonics was performed at 1 and 3 MHz, with the sound coupled to the test panel by 3/16 inch water jets. The resulting recording with the best definition of the built-in flaws is shown in Figure 11-2. This was prepared at 3 MHz with the received signals logarithmically compressed. Pulse-echo ultrasonic recordings were obtained at 5 MHz using a facsimile plotter.

Another procedure evaluated consisted of holding a film containing thermally-quenched phosphors against the test surface with a vacuum. The panel was then thermally cycled with a hand-held hot air gun while the phosphors were illuminated with an ultraviolet lamp in a darkened room.

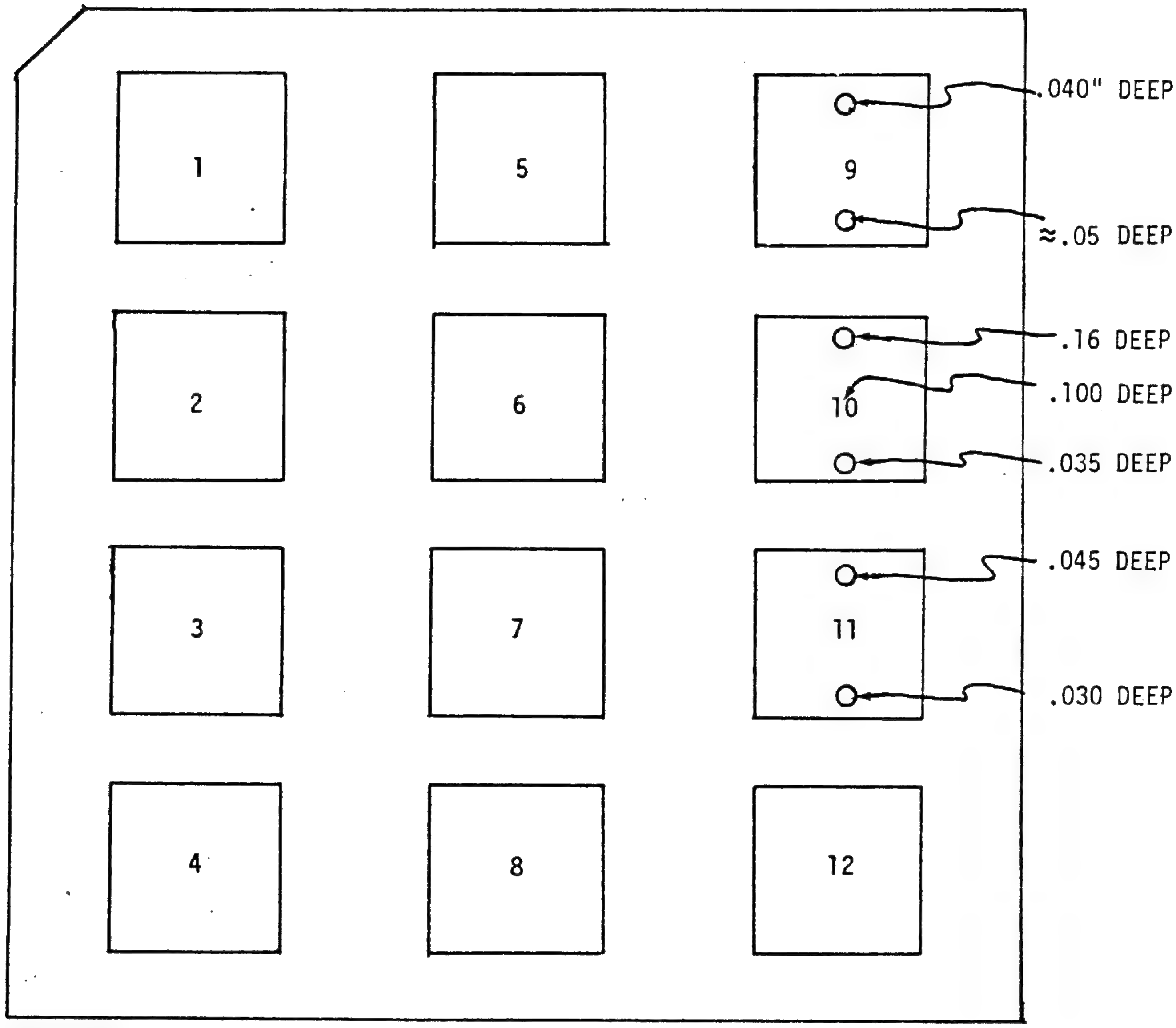
Radiographs were prepared at 31 Kv, 25 mam, TFD -.36 inches on type AA film.

Conventional tests using commercial bond test instruments were performed. The Fokker Bond Tester, a Sondicator and Harmonic Bond Tester were used to

examine the panel, as well as a derivative of the Sondicator, the Audible Bond Tester.

The results of the above tests are summarized in Table 11-1. A positive indication of the flaws is noted by an "X" in the table. As noted from this data, the through transmission ultrasonic technique provided the best flaw detection capability.

PROCURED 36 PLY LAMINATE = .480 INCHES
BOND EA9628 ADHESIVE 90 MINUTES AT 50 PSI



DEFECTS

1. PARTING AGENT
2. .5 MIL TEFLON
3. 2 MIL TEFLON
4. 5 MIL KAPTON AND PARTING AGENT
5. NO ADHESIVE 1.5 INCHES SQUARE
6. AIR BAG (FEP)
7. NO ADHESIVE - FEP (2 MIL)
8. NO ADHESIVE - 181 FABRIC
9. 1/4" DRILLED HOLE - 2-3 PLIES DEEP
   1/2" DRILLED HOLE - 2-3 PLIES DEEP
10. 1/8" DRILLED HOLE - 20 PLIES DEEP
    1/8" DRILLED HOLE - 10 PLIES DEEP
    1/8" DRILLED HOLE - 5 PLIES DEEP
11. 1/4" DRILLED HOLE - 3-4 FEP FILM
    1/2" DRILLED HOLE - 3-4 FEP FILM
12. PAPER 1.5" sq. - TOP

FIGURE 11-1 COMPOSITE PANEL FLAW DESCRIPTIONS

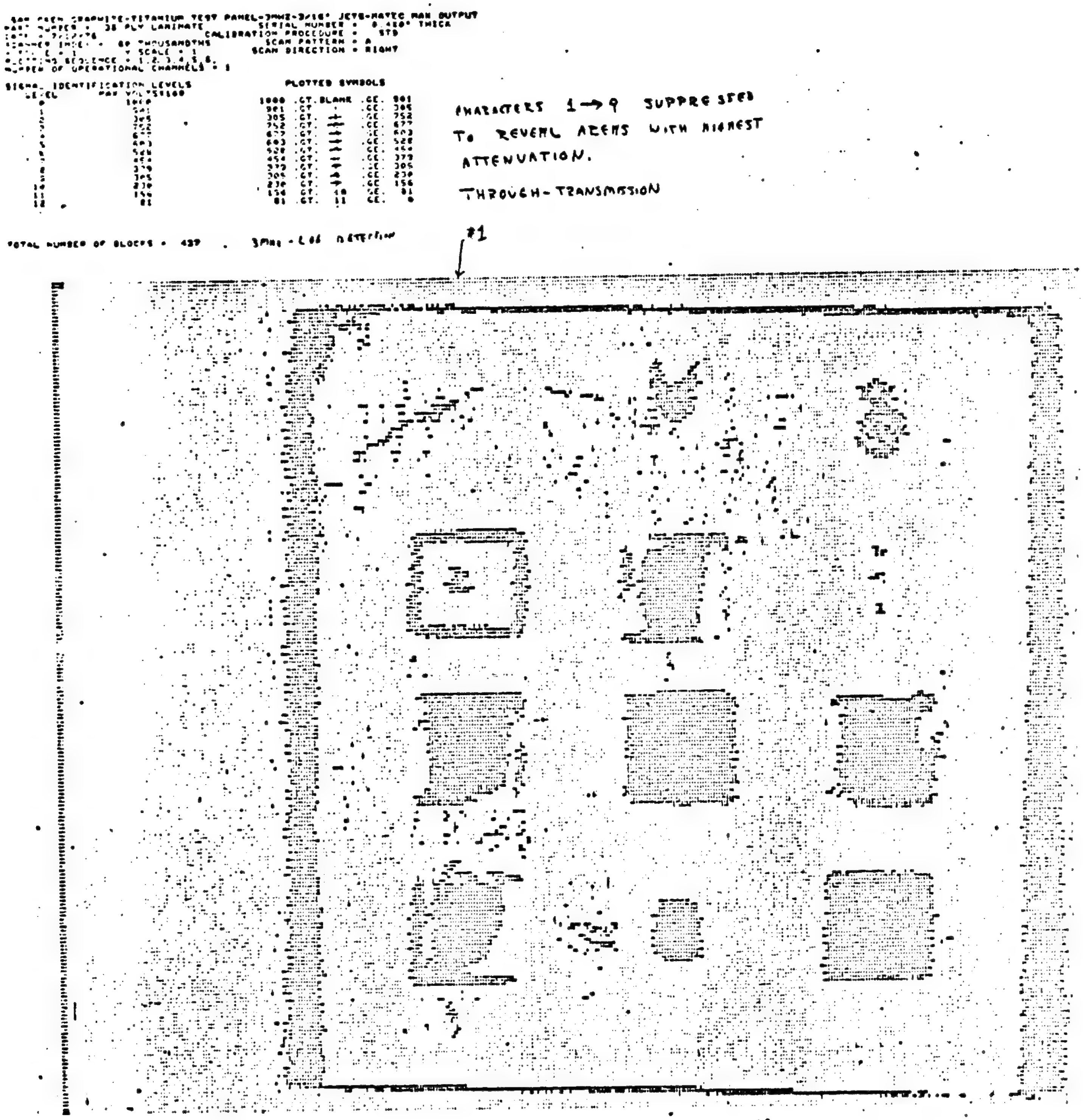


FIGURE 11-2 THROUGH TRANSMISSION ULTRASONIC RECORDING

TABLE 11-1

NONDESTRUCTIVE EVALUATION SUMMARY

NDT METHODS

FLAW	ULTRASONIC THRU-TRANS-MISSION	ULTRASONIC PULSE-ECHO	THERMAL	AUDIBLE BOND TESTER	X-RAY	FOKKER	HARMONIC BOND TESTER	SONDI-CATOR
1	X							
2	X					X		
3	X					X	X	
4	X	X				X	X	
5	X		X		X	X		
6	X	X		X	X	X	X	
7	X	X	X	X	X	X	X	X
8	X	X	X	X	X	X	X	X
9	X				X	X		
10	X	X			X			
11	X	X	X	X	X	X		X
12	X	X				X		

ACTIVE SHEET RECORD

SHEET NO.	REV LTR	ADDED SHEETS				SHEET NO.	REV LTR	ADDED SHEETS			
		SHEET NO.	REV LTR	SHEET NO.	REV LTR			SHEET NO.	REV LTR	SHEET NO.	REV LTR
1						46					
2						47					
3						48					
4						49					
5						50					
6						51					
7						52					
8						53					
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10						55					
11						56					
12						57					
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22						67					
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25						70					
26						71					
27						72					
28						73					
29						74					
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38						83					
39						84					
40						85					
41						86					
42						87					
43						88					
44						89					
45						90					

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ACTIVE SHEET RECORD

SHEET NO.	REV LTR	ADDED SHEETS				SHEET NO.	REV LTR	ADDED SHEETS			
		SHEET NO.	REV LTR	SHEET NO.	REV LTR			SHEET NO.	REV LTR	SHEET NO.	REV LTR
91						B-1					
92						B-2					
93						B-3					
94						B-4					
95						B-5					
96						B-6					
97											
98											
99											
100											
101						C-1					
102						C-2					
1-3											
104											
105											
106											
107											
108											
109											
110											
111											
112											
113											
A-1											
A-2											
A-3											
A-4											
A-5											
A-6											
A-7											
A-8											
A-9											
A-10											
A-11											
A-12											
A-13											
A-14											
A-15											
A-16											
A-17											

DO 6000 2155 ORIG. 4/71

REVISIONS

LTR	DESCRIPTION	DATE	APPROVAL

PREPARED BY: D.A. SORENSON

6 November 1978

APPROVED BY: [signature]

APPENDIX A

APPROVED BY: [signature]

COMPOSITE FLAP HINGE BLOCK INSTALLATION PROCEDURES (ANNOTATED) 1/3/79

A. REFERENCE DRAWINGS

Drawing Number	Drawing Title	Sheets
SK11-030827	Hinge Rework - Aft Flaps	1
SK11-030832	Hinge Rework - Forward Flaps	1
25-56162	Aft Foil Assembly (Rework)	1,2
25-56165	Linkage Installation - Elevon	1,2
25-56167	Elevon Installation - Aft Foil	1,2,3,4
25-56177	Linkage Details, Elevon	1,2
PCH-1-518-1993318	Aft Center Foil/Flap Arrangement and Details	3,5
180-56500	Flap, Assembly, Aft Inboard-Starboard	1,2
180-56501	Spar/Crank Assembly, Aft Inboard-Starboard	1
180-56502	Cover Assembly, Upper and Lower, Aft Inboard-Stbd	1,2
180-56503	Machine Details, Aft Inboard-Starboard	1
180-56504	Machine Details, Aft Inboard-Starboard	1

- REMOVED METAL FLAP FROM PCH-1 ON: 11/29/78
- U.S NAVY DELIVERED FLAP TO BOEING ON : 11/30/78
- COMMENCED COMPOSITE FLAP WORK AT BOEING ON: 11/30/78
- COMPLETED COMPOSITE FLAP WORK AT BOEING ON: 12/6/78
- U.S. NAVY PICKED UP COMPOSITE & METAL FLAPS ON: 12/11/78

B. PREREQUISITES

1. Hoist capable of 500 pounds lift.

2. Straps for handling 350 pound composite flap.

3. Measuring equipment capable of measuring critical dimensions up to 7 feet long.

4. Two work benches, 8 feet long by 3 feet wide.

5. ~~AN960-1016 type~~ Metal washers for ~~5/8"~~ 1/2" bolts (30 required).

6. Equipment for template drilling of close ream holes for ~~NAS 590-66~~ NAS1608-66 bolts (~~.6255/.6245~~) (.5005/.4995). (Drawing Change Required)

7. TURCO 5351 stripping solvent (three gallons). (NOT REQUIRED)

8. EPON 934 bonding adhesive (one-half pint).

9. Fitup jig (one inch plate or equivalent bolted down to work bench allowing a two inch overhang on bench). (Reference H-7308-1 sketch) (Fabricated on 11/27/78)

10. Basic tools for removal of various fasteners, etc.

11. Torque wrench (minimum = 100 foot pounds).

✓ 12. Calipers.

✓ 13. Feeler gages.

✓ 14. Press equipment for bushing & bearing removals & installations.

✓ 15. ~~NAS 509-18 type~~ Nuts for ~~NAS 590-68~~ NAS1608-66 bolts (~~5/8-18~~ 1/2-20 thread). (Drawing Change Required.)

X 16. Shim material. (NOT REQUIRED)

✓ 17. Punches for match marking (numbered punches).

X 18. Capability of heating hinge blocks to ≈ 450°F. (NOT REQUIRED)

✓ 19. 25-56167-39 shims (ten required). (GFE) (ONLY TWO USED - #1 HINGE BLOC

✓ 20. 25-56167-14 bushings (five required). (GFE) (USED OLD BUSHINGS)

✓ 21. ~~NAS 590-66~~ NAS1608-66 bolts (ten required). (GFE) (USED OLD BOLTS) (Drawing Change Required)

✓ 22. Micrometers (2.0-3.0 inch and 4.0-5.0 inch).

✓ 23. Taper end of composite flap hinge pin per Sketch H-7308-1. (Accomplished on 11/28/78)

C. PROCEDURES

NOTE: RECEIVED METAL FLAP AT BOEING ON 11/30/78

Upon receipt of the starboard inboard metal flap (with hinge blocks attached) from PCH-1, accomplish the following:

✓ CAUTION: Use extreme care not to damage the cable bundle for the composite flap strain gages.

11/30/78 ✓ 1. Lay both the metal flap and composite flap on a bench (or benches) for a general overall visual inspection. (Provide cushion for composite flap.)

NOTE: Composite Flap Crank arm is not parallel with the flapedge. (Elevon linkage should tolerate the offset.

- Record questionable concerns as required.

11/30/78 ✓ 2. Check hinge blocks in metal flap to see if they are free and can be moved spanwise to butt up against spacer washers in both directions.

- Hinge blocks were very tight.
- Spacer washers installed on #1 Hinge block only.

- Record results.

11/30/78 ✓ 3. If possible, move all five hinge blocks in the same direction to butt up against their respective spacer washers (preferrably, move away from flap crank arm end).

- Hinge blocks were left in The position "As received"

12/1/78 & 12/4/78 ✓ 4. Position metal flap hinge blocks on fitup jig. Assuring Item 3 above is still satisfied, locate and drill required close ream holes through the fitup jig (hole tolerances for close ream = ~~.6255/.6245~~ .5005/.4995).

X NOTE: Depending on straightness of fitup jig and spanwise contour of metal flap, some shimming may be required under some of the hinge blocks. (NO SHIMS REQUIRED)

✓ 5. Using NAS ~~590-66~~ 1603-66 hinge block bolts, washers, and nuts provided, bolt metal flap hinge blocks to fitup jig. Support will be required to hold metal flap in the horizontal plane (match mark both ends of flap on fitup jig).

1/1/78

✓ 6. Obtain and record all critical dimensions for both the metal and composite flap noted on Attachments 1, 2, and 3. Identify hinge blocks as No. 1, 2, 3, 4, and 5. Match mark the metal flap.
(See Tables I, II, III & IV for dimensional data)

12/1-6/78

✓ 7. Assuring that portion required of Item 6 above is completed satisfactorily and the hinge blocks are securely bolted to the fitup jig, remove the metal flap.

12/4/78

✓ NOTE: After the metal flap is removed, replace (on the metal flap) each hinge block pin, spacer washers, captive cover, and fasteners in their respective locations.

12/4/78

✓ 8. With the hinge blocks bolted to the fitup jig, check alignment and fit of the new composite flap single hinge pin.

12/4/78

- Record results.

- Single Hinge pin fit into all five hinge blocks satisfactory
- Recommend using old Hinge block bushings which are in excellent condition. Approved by HYSTU on 12/4/78.

✓ NOTE: If an alignment problem exists, a resolution will be recommended to the U.S. Navy for approval (e.g., one new hinge block may be required which can be match drilled to foil on installation).
No Alignment Problems.

✓ 9. Inspect hinge block fabroid bushings for wear etc., use new bushings for

12/4/78

reference).

- Record results.

NOTE: If bushings appear in good shape, U.S. Navy could go along with re-using per Vern Whitehead discussion on 3 November 1978 with D. A. Sorenson.

- New bushings to be used when metal flap is re-installed.

- HYSTU CODE 1154.4 (V. Whitehead) approved use of old bushings based on recommendations by Boeing during telecon on 12/4/78 with D.A. Sorenson.

10. If bushings need to be replaced (assure each hinge block is identified for location on fitup jig), remove hinge block and soak for approximately 24 hours in TURCO 5351 stripper. This should allow the EPON 934 bonded bushing to be removed.

NOT REQUIRED (used Old Bushings)

NOTE: If this does not work, heating of the entire hinge block to 450^{0} $\pm$ 25^{0}F should allow removal of bonded bushing.

11. Install new "GFE" bushings using EPON 934.

NOT REQUIRED (used Old Bushings)

12. Replace hinge blocks in their respective positions on the fitup jig.

NOT REQUIRED (Hinge Blocks were never removed)

13. If desired, repeat alignment and fit check of new composite flap single hinge pin.

(NOT REQUIRED)

12/4/78

14. Using the critical dimensions recorded in Item 6 above, determine the washer spacer thickness required for each side of each hinge block to assure repositioning the blocks as they were in the metal flap. Match mark washer spacers for their respective hinge block.

- Spacer Washers installed for #1 Hinge Block only as agreed during Telecon w/ HYSTU CODE 1154.4 (V. Whitehead) on 12/1/78. (Same as Metal Flap)

NOTE: SPACER THICKNESS (CRANK ARM END) = 0.100
" " (OPPOSITE) = 0.074

1/5/78 ✓ 15. Move the composite flap up to the fitup jig and commence installing the single hinge pin, inserting the match marked spacer washers during pin installation. Assure hinge pin retaining bolt hole is properly aligned. Spacer washers installed in #1 Hinge Block Only

✓ NOTE: Freezing of hinge pin (i.e., using dry ice) may be desirable for ease of installation and to prevent bushing damage during pin installation. (NOT REQUIRED)

12/5/78 ✓ 16. Install hinge pin retaining bolt.

12/6/78 ✓ 17. Install composite flap (-2) end plate per drawing 180-56504.
NOTE: (3) #10-32 Ti countersunk screws were installed to insure securing the -2 end plate. Drawings will be updated to reflect this change.

12/6/78 ✓ 18* Check composite flap crank arm pedestal bearing for proper fit-up.
Appears Satisfactory. (Requires Ship Check for final assurrance)

12/6/78 ✓ 19. Notify U.S. Navy the metal and composite flaps are ready for pick-up.

U.S. Navy picked up both flaps on 12/11/78. Installation of Composite Flap on PCH-1 Commenced on 12/12/78.

NOTE: See separate procedures for Ship installation commen[illegible]

* - The flap crank arm pedestal bearing housing isolating bushing (PCH-1 drawing Part No. 25-56177-46) had to be machined out of the housing to accommodate the new composite flap crank arm pedestal bearing
- When the metal flap is re-installed on PCH-1, a new isolating boshing (25-56177-46) will be required to accommodate the 7672 spherical bearing.

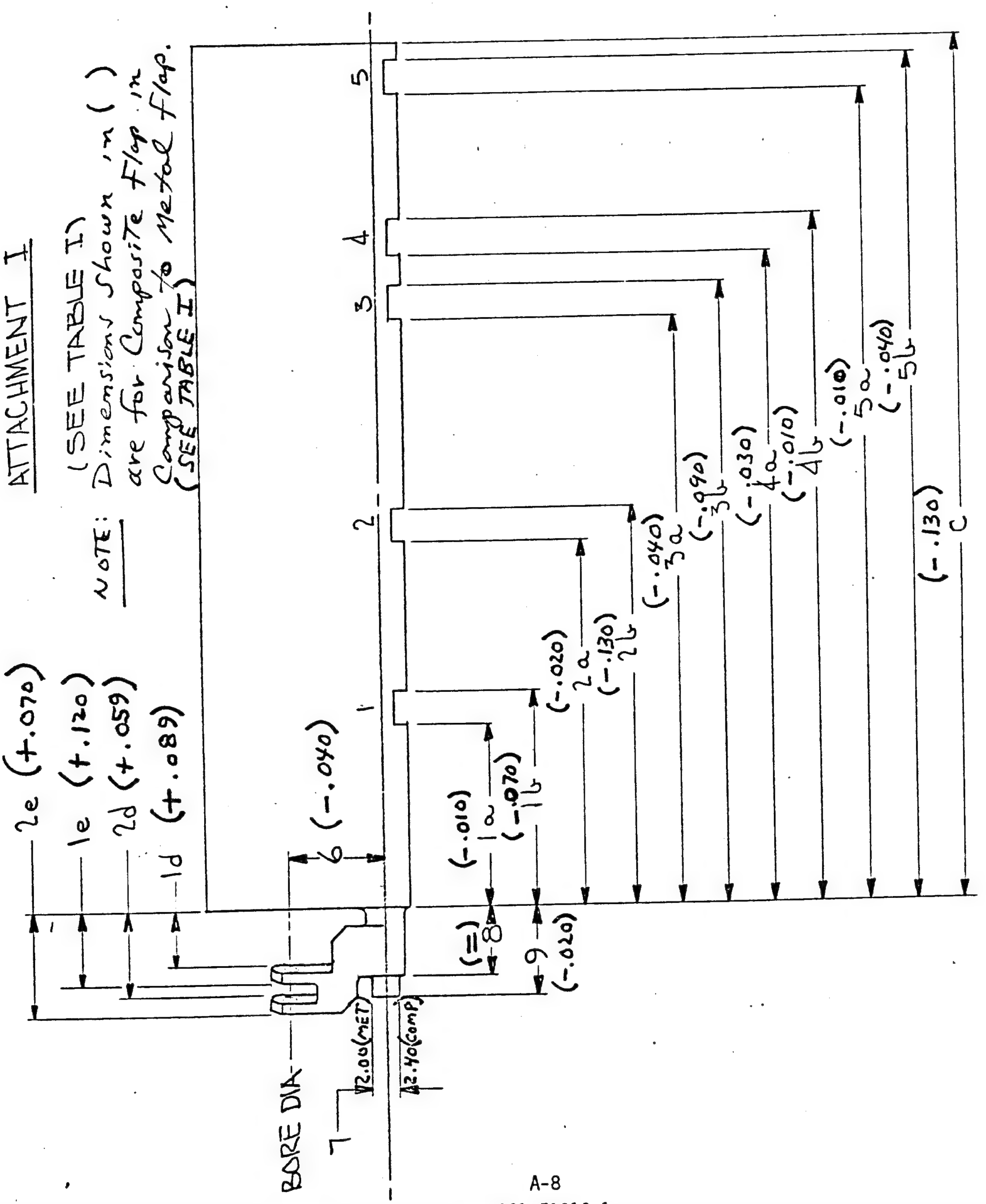

ATTACHMENT I
(SEE TABLE I)
NOTE: Dimensions shown in ( ) are for Composite Flap in Comparison to Metal Flap. (SEE TABLE I)
2e (+.070)
1e (+.120)
2d (+.059)
1d (+.089)
6 (-.040)
1
2
3
4
5
(-.010) 1a
(-.070) 1b
(-.020) 2a
(-.130) 2b
(-.040) 3a
(-.090) 3b
(-.030) 4a
(-.010) 4b
(-.010) 5a
(-.040) 5b
(-.130) C
(=) 8
9 (-.020)
BORE DIA
7
2.00 (MET)
2.40 (COMP)

TABLE I

METAL & COMPOSITE FLAP CRITICAL DIMENSION CROSSCHECK

(SEE ATTACHMENT I)

DIMENSION LINE		DIMENSION (INCHES)		
		METAL FLAP	COMPOSITE FLAP	
1a	12/4/8	17.40	17.39	12/1/8
1b		20.65	20.58	
2a		34.56	34.58	
2b		37.80	37.67	
3a		55.48	55.44	
3b		58.71	58.62	
4a		61.65	61.62	
4b		64.87	65.86	
5a		76.52	76.51	
5b		79.76	79.72	
c		81.61	81.48	
1d		5.128	5.181	
2d		7.928	8.017	
1e		6.70	6.82	
2e		9.57	9.64	
6	12/1/8	8.92	8.88	
7		2.000	2.400	
8		6.30	6.30	
9		8.36	8.34	
BORE DIA.		2.250	2.250	

NOTE: Dimensions Shown are for Hinge Block Locations for the Metal flap

ATTACHMENT II

(SEE TABLE II)

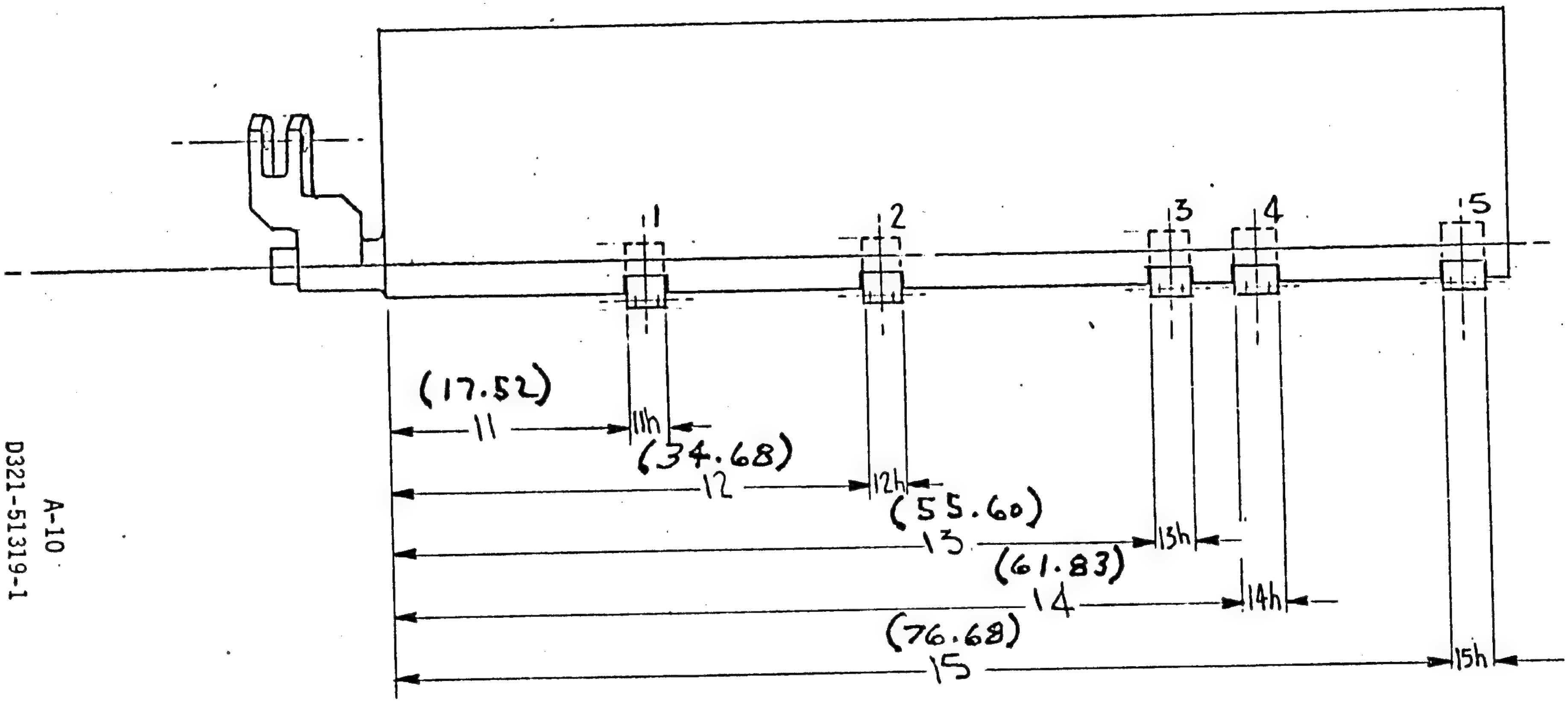


TABLE II

METAL & COMPOSITE FLAP HINGE LOCATION (AS BUILT)

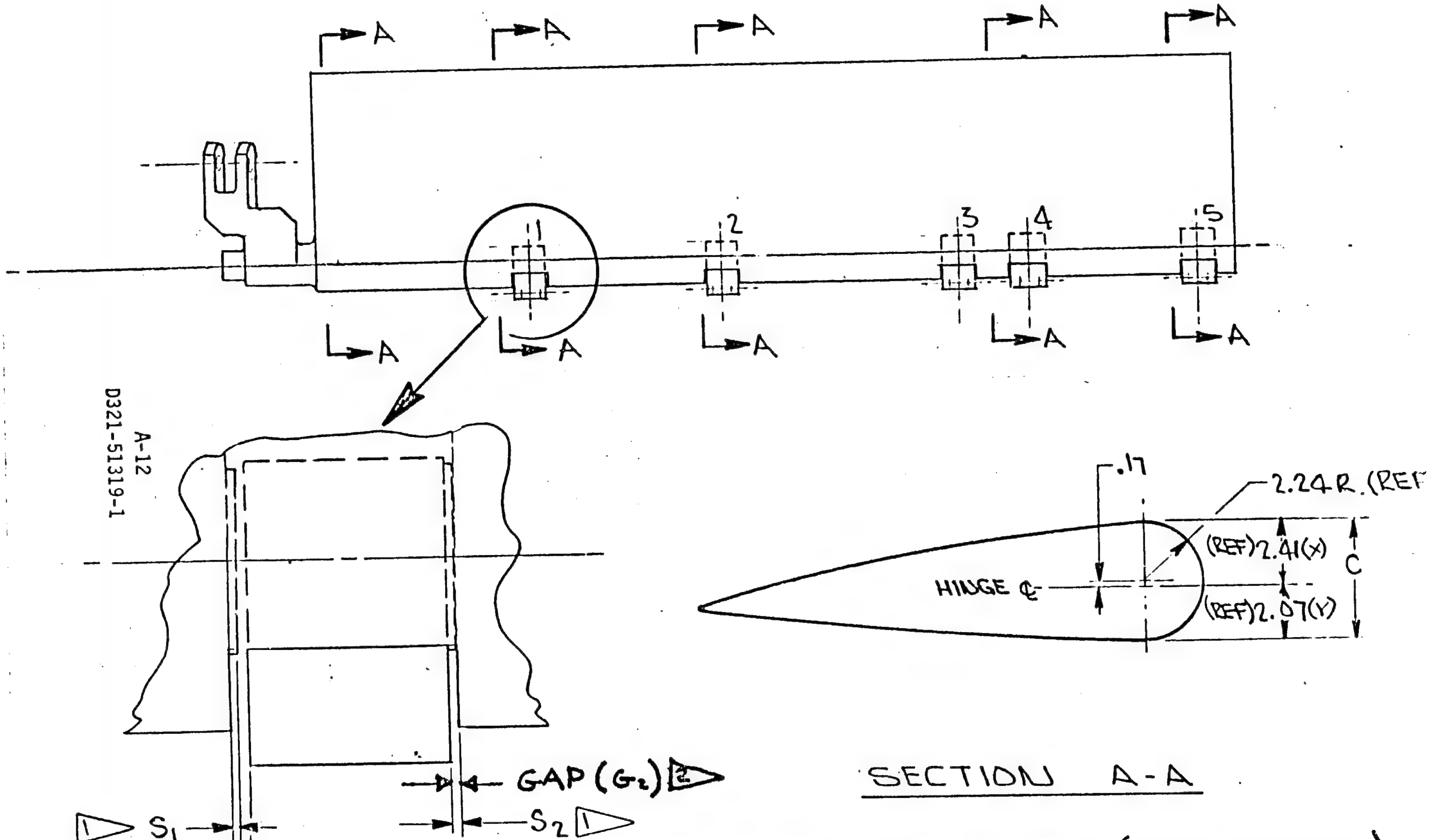
(SEE ATTACHMENT II)

DIMENSION LINE		DIMENSION (INCHES)	
		METAL FLAP	COMPOSITE FLAP
#1	11 12/14/78	17.52	17.52
	11h	3.03	3.03
* #2	12	34.68	34.66
	12h	3.07	3.07
* #3	13	55.60	55.59
	13h	3.06	3.06
* #4	14	61.83	61.83
	14h	3.06	3.06
* #5	15	76.68	76.68
	15h	3.07	3.07

* Hinge Block Can Be Moved Spanwise on Installation for Hole Line up. No Spacer Washers were Installed on These Blocks.

ATTACHMENT III

(SEE TABLES III & IV)



SECTION A-A

1 APPLIES TO HINGE BLOCK #1 ONLY (SPACER THICKNESS) ~~OPTIONAL TO MIC AFTER REMOVAL~~

2 APPLIES TO ALL HINGE BLOCKS (GAP DIMENSION)

TABLE III

SPACER THICKNESS & GAP

(SEE ATTACHMENT III)

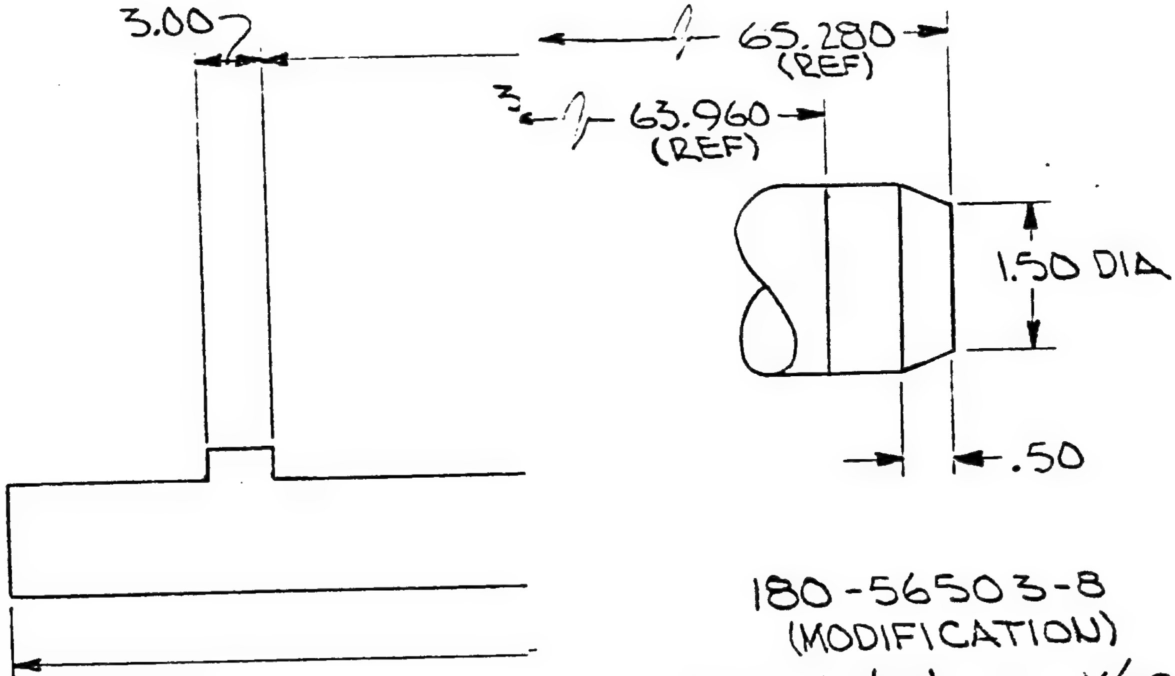
DIMENSION LINE			DIMENSION (INCHES) METAL FLAP	DIMENSION (INCHES) COMPOSITE FLAP	
HINGE #1	~~S_T~~ G_1	12/1/8	.110	.115	12/5
✓	~~S_T~~ G_2		.135	.089	
✓	~~GAP~~ S_1 S_2		.119 .121	.100 .074	
HINGE #2	~~S_T~~ G_1		.116	.099	12/6
✓	~~S_T~~ G_2		.133	.071	
✓	~~GAP~~		NO SPACERS	NO SPACERS	
HINGE #3	~~S_T~~ G_1		.132	.130	
✓	~~S_T~~ G_2		.120	.049	
✓	~~GAP~~		NO SPACERS	NO SPACERS	
HINGE #4	~~S_T~~ G_1	12/4/8	.199	.166	
✓	~~S_T~~ G_2		.064	.015	
✓	~~GAP~~		NO SPACERS	NO SPACERS	
HINGE #5	~~S_T~~ G_1		.091	.120	
✓	~~S_T~~ G_2		.164	.046	
✓	~~GAP~~		NO SPACERS	NO SPACERS	

TABLE IV

CHORD CHECK

(SEE ATTACHMENT III)

DIMENSION LOCATION		DIMENSION (INCHES) METAL FLAP	COMPOSITE FLAP
CRANK END	C 12/4/8	4.489	4.400 12/4/
✓	X	NOT READABLE	NOT READABLE
✓	Y	" "	" "
HINGE #1	C	4.529	4.558
✓	X	2.391	2.454
✓	Y	2.076	2.108
HINGE #2	C	4.468	4.558
✓	X	2.421	2.454
✓	Y	2.046	2.108
HINGE #4	C	4.423	4.541
✓	X	2.431	2.454
✓	Y	1.945	2.108
HINGE #5	C	4.420	4.547
✓	X	2.361	2.454
✓	Y	2.018	2.108



180-56503-8
(MODIFICATION)
Completed on 11/28/78

SK H-7303-1

NOTE: These visual [illegible]
from the metal flap "As Installed"
on the ship on 11/8/78. They were
scribed on an aluminum angle and
the measurements were taken from
the angle @ Boeing on 11/9/78.

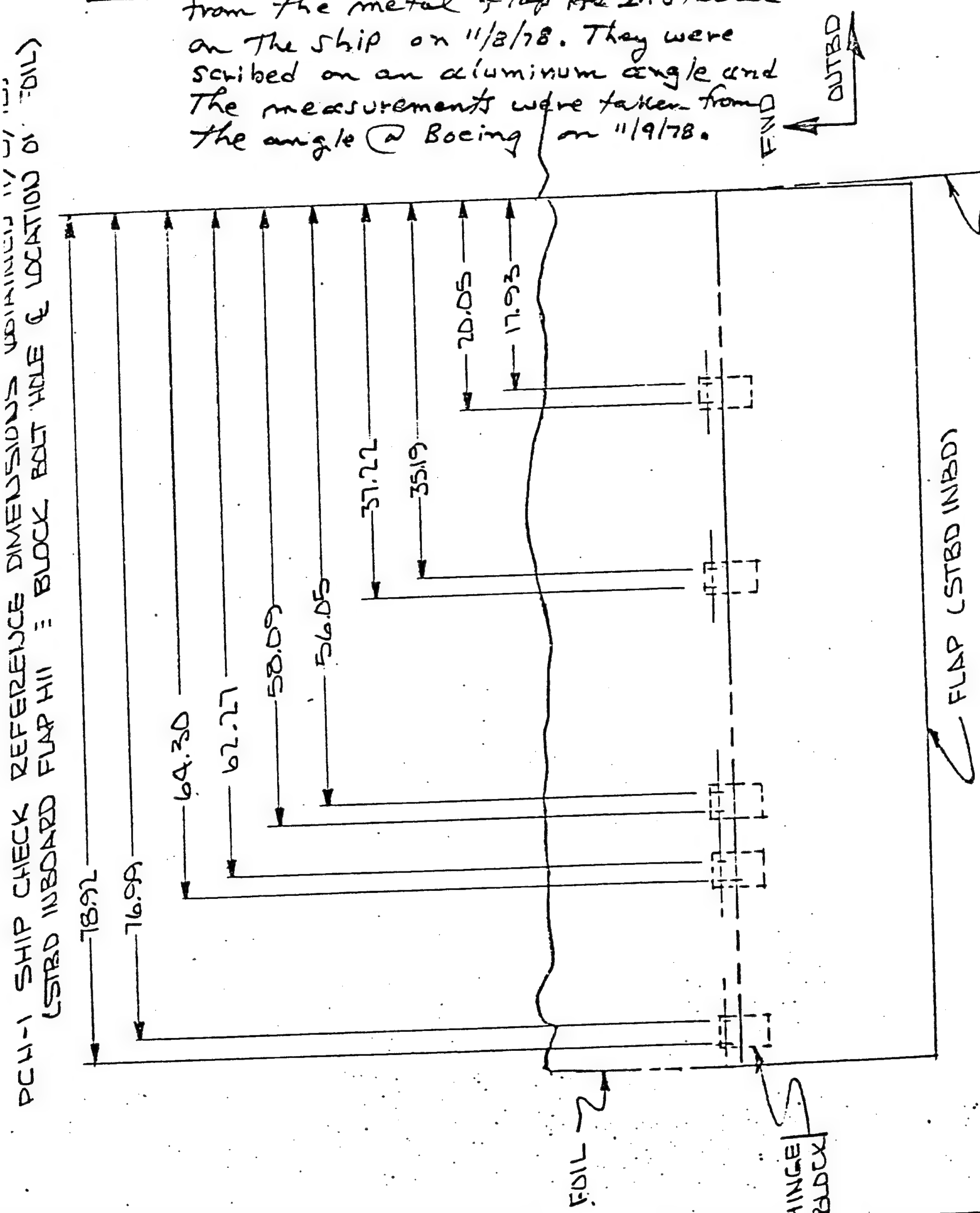


FIG H-7308-2

The following dimensional information was recorded & is included as part of This data package for future reference as required.

I. Hinge Block Bushing I.D. check:

OLD BUSHINGS	NEW BUSHINGS
Hinge Block #1 = 2.005"	Bushing #1 = 2.006"
" " #2 = 2.004"	" #2 = 2.005"
" " #3 = 2.004"	" #3 = 2.005"
" " #4 = 2.005"	" #4 = 2.005"
" " #5 = 2.004"	" #5 = 2.006"

NOTE: Based on The above dimensional check & inspection of The bushings, iT was recommended (& approved by HYSTU CODE 1154.4) to re-use the old bushings.

II. Hinge Pin Bushing Surface Area Diameter Check:

NOTE: The 180-56503-8 Hinge Pin (Ti) bushing surface areas (Denoted By $\boxed{2}$> on Drawing 180-56503) showed evidence of scratches. The pin was put in a lathe & the surfaces were cleaned up. Before & After machining diameter dimensions were as follows:

BEFORE MACHINING	AFTER MACHINING
Hinge Bushing Surface #1 = 2.0023"	#1 = 2.0021"
" " " #2 = 2.0020"	#2 = 2.0017"
" " " #3 = 2.0021"	#3 = 2.0017"
" " " #4 = 2.0026"	#4 = 2.0019"
" " " #5 = 2.0021"	#5 = 2.0020"

D. a. Sorenson 12/4/78

PREPARED BY: D.A. Sorenson 13 November 1978

APPROVED BY: A.F. Rand

APPENDIX B

APPROVED BY: [illegible]

PCH-1 COMPOSITE FLAP-SHIP INSTALLATION PROCEDURES (ANNOTATED) 12/21/7[illegible]

A. REFERENCE DRAWINGS

Drawing Number	Drawing Title	Sheets
SK11-030827	Hinge Rework - Aft Flaps	1
SK11-030832	Hinge Rework - Forward Flaps	1
25-56160	Foil System Installation - Aft	1,2,3
25-56162	Aft Foil Assembly (Rework)	1,2
25-56164	Pod Installation - Foil/Strut	1,2,3
25-56165	Linkage Installation - Elevon	1,2
25-56167	Elevon Installation - Aft Foil	1,2,3,4
25-56175	Support Details - Fiberglass Pod Fairing	1,2,3
25-56176	Fairing Details - Fiberglass Pod	1,2
25-56177	Linkage Details, Elevon	1,2
25-56179	Fairing - Aft Strut	1
PCH-1-518-1993318	Aft Center Foil/Flap Arrangement and Details	3,5
180-56500	Flap, Assembly, Aft Inboard-Starboard	1,2
180-56501	Spar/Crank Assembly, Aft Inboard-Starboard	2
180-56502	Cover Assembly, Upper and Lower, Aft Inboard-Starboard	1,2
180-56503	Machine Details, Aft Inboard-Starboard	1
180-56504	Machine Details, Aft Inboard-Starboard	1

COMPOSITE FLAP PICKED UP AT BOEING ON: 12/11/7[illegible]
STARTED INSTALLATION ON: 12/12/78
COMPLETED " " : 12/14/78
PERFORMED FUNCTIONAL CHECK: 12/15/78
SCHEDULED FLAP/LINK CALIB.: 1/22/7[illegible]

<u>CAUTION</u>

The composite flap is a Research and Development Project aimed towards evaluating new lightweight materials for application on foil/strut systems for future hydrofoils.

Extreme care should be taken while handling and installing this flap on PCH-1. Protective pads should be used as required to prevent damage.

Also, provide protection at all times for composite flap and elevon link strain gage instrumentation cable bundles.

B. <u>PREREQUISITES</u>

1. Composite flap hinge block and pedestal bearing installations completed by The Boeing Company. Completed on 12/6/78

2. New ~~NAS590-66~~ NAS1608-66 bolts (10 required).
   <u>NOTE</u>: Drawing change required.

3. New SK11-030832-141 nuts (10 required). (1/2 x 20 Thread)
   <u>NOTE</u>: Drawing change required.

4. New 5-427-14 "O" Rings (40 required)(reference 25-56167).

5. New flap crank arm pedestal bearing and washer.
   Provided By Boeing under Composite Flap Contract.

6. Areas such as foil hinge block housings, flap wiper areas, crank arm pedestal bearing areas, cleaned and painted as required. (SATISFACTORY)

7. Provide padded wedges as required to place over composite flap trailing edge while forcing flap hinge blocks into foil housing. (USED FLAP CALIBRATION WEDGE TOOL)

8. Proseal 890 B-1/2 Sealant (1 quart kit required).

9. Equipment required to position and hold composite flap during installation.

10. Tools as required for fastener installations, etc.

11. Photographic coverage of composite flap installation. (ACCOMPLISHED BY BOEING ON 12/13/78)

12. Zinc Chromate Primer (1 quart required).

13. Elevon links strain gaged, calibrated, and returned to PCH-1 for installation. COMPLETED BY BOEING ON 12/11/78

14. Elevon attachment links, pins, etc., cleaned as required for reinstallation. (SATISFACTORY)

15. Shim material. (NONE REQUIRED)

16. New crank arm pedestal bearing housing flange bolts (SPS #20097N-10F-20B) (4 required)

✓ 17. Starboard side fiberglass pod and strut trailing edge fairings removed.

✓ 18. Touch up paint (for foil, strut, pod, and metal flaps).

✓ 19. Availability of ships hydraulic system and automatic control system as required.

C. INSTALLATION PROCEDURES

2/12/78 ✓ 1. Assuring the PCH-1 is ready to receive the composite flap (all interface areas cleaned and necessary hardware, tools, etc., are available) move the composite flap up into position for installation.

✓ CAUTION: Extreme care must be taken to not damage the composite flap and instrumentation cables.*

12/12/78 ✓ 2. Visually inspect areas such as: the flap crank arm pedestal bearing, flap hinge block foil housings, flap wipers, etc., to assure everything appears satisfactory for composite flap installation.

(SATISFACTORY)

12/12/78 ✓ 3. Install the "O" rings in the hinge blocks (4 per block required). Move composite flap and guide the hinge blocks into the foil housings.*

USED SILICONE GREASE ON HINGE BLOCKS TO EASE INSTALLATION.

NOTE: ✓ a. Use of padded wedges may be required to force the hinge blocks into place.

✓ b. Also, drift pins may be required to align flap hinge block body bound bolt holes to the existing foil bolt holes.

✓ c. Foil may require flexing by using appropriate jacks to aid in assembling hinge blocks to foil slots. (NOT REQUIRED)

* Slight delamination accidentally occurred to the Titanium/graphite epox on the bottom leading edge of the most inboard hinge block opening. This will be ultrasonically checked and repaired. Titanium clips will placed on all hinge block leading edges to prevent further damage.

12/12/78 4. Inspect the flap crank arm pedestal bearing housing flange to assure the bolt holes line up with the strut pod structure holes. (SATISFACTORY)

NOTE: Approximately 3/16" material was removed from the foil trailing edge housing to assure clearance for the composite flap leading edge. (Upper surface only). Drawing update required.

12/12/78 5. If everything appears satisfactory, commence with the installation of flap hinge block bolts and nuts and pedestal bearing bolts.

NOTE: a. Dip bolts and nuts in wet Zinc Chromate prior to installation.

b. Shimming of the flap crank arm pedestal bearing housing flange may be required. (NOT REQUIRED)

12/12/78 & 3/78 6. When the bolts are properly torqued* and before elevon control rod linkage hook-up, use the flap calibration wedge tool (padded) to move the flap up and down through its full travel to assure that everything appears satisfactory (i.e., no interference** and/or binding occurs and that full normal travel is attained; approximately 19 degrees trailing edge down and 13 degrees trailing edge up).

*HINGE BLOCK BOLTS TORQUE = 75 FT. LBS (USED IMPACT WRENCH.

*PEDASTAL FLANGE BOLTS TORQUE: 120 FT. LBS.

12/13/78 7. Install the elevon links and pins (this includes the starboard outboard elevon link).

12/18-21/78 8. Route and install the composite flap and elevon links strain gage wire bundles into the PCH-1 instrumentation system junction box in the machinery space (Boeing to supply procedures and accomplish).

**- Interference occurred between the composite flap crank arm clevis & the elevon link. This was resolved by grinding a small amount off the elevon link & the remainder off the forward side of the crank arm clevis. Drawings will be updated to reflect the above.

- The composite flap elevon link outboard strain gages wires were damaged due to interference with the flap crank arm clevis. Due to the extremely low output of these particular gages, they will not be repaired as agreed to by DTNSRDC & DTNSRDC-HYSTU.

9. Fill the flap hinge block bolt head and nut cavities in the foil with sealant (Proseal 890) and fair.
TO ACCOMPLISH IN JANUARY 1979 WHEN OTHER FAIRING WILL BE ACCOMPLISHED.

12/15/78 10. Prior to installing the fiberglass pod and strut trailing edge fairings, activate the ships service foilborne hydraulic system and the automatic control system (in the foilborne mode). Move the aft flaps through full travel with helm commands to verify satisfactory operation and freedom of movement of the instrumentation cables.
ACCOMPLISHED ON 12/15/78 (SATISFACTORY)

11. Install fiberglass pod and strut trailing edge fairings.
TO ACCOMPLISH IN JANUARY 1979

12. After fiberglass pod and strut trailing edge fairings are installed, operate the aft flaps through full travel again (using hydraulics, ACS, and helm inputs) to assure everything is satisfactory.
TO ACCOMPLISH IN JANUARY/FEBRUARY 1979.

13. Touch up paint as required.
TO ACCOMPLISH IN JANUARY/FEBRUARY 1979.

* 14. Proceed with PCH-1 aft starboard inboard composite flap and both starboard inboard and outboard elevon links dock calibrations (refer to Boeing procedure being transmitted under separate cover).
PRESENTLY SCHEDULED TO BE ACCOMPLISHED DURING THE WEEK OF 22 JANUARY 1979.

* It may be desirable to accomplish these calibrations before Step 11 above. This would provide assurance that the strain gage cabling is satisfactory before installing the fiberglass pod and strut trailing edge fairings. NOTE: The calibrations will be accomplished prior to installation of the fiberglass pod & strut trailing edge fairings.

PCH-1 COMPOSITE FLAP INSTALLATION
STRAINGAGE WIRE ROUTING PROCEDURE

After the flap is installed, the strain gage wiring bundle is to be routed up the trailing edge of the starboard aft strut, through the drip loop at the top of the strut, and terminated in the instrumentation junction box in the engine room.

The cable bundle comes out of the flap through the hinge pin on the crank arm. This bundle consists of 158 individual wires enclosed in an overall slip-on shield.

A flex loop is to be established in this cable bundle to allow full flap motion (20 degrees down and 13 degrees up), and provide minimum strain to the wires. Consideration must be given to the motion of all mechanical linkages in this area to prevent binding and chaffing of the wire bundle. ✓ 12/18/78

The shield over this cable bundle may be removed in this area and a nylon spiral wrap covering may be used to help contain and protect the wires as well as provide a flexible interface.

The bundle of wires to be routed up the trailing edge of the strut will consist of the 158 wire bundle from the composite flap and four 4-conductor cables from the two flap links in this area.

All unused instrumentation wiring presently installed in this area will be removed and can be used for "pull wires" to route the new wiring in.

An instrumentation conduit exists which will handle all these cables. This conduit starts within the pod area where the flex joint for the composite flap cable is made and where a flex joint is made for the eight flap link cables.

This conduit extends up the trailing edge of the strut into the strut base (at the top of the strut). The strut bases must be raised to the main deck level

so that the access panels may be removed from the strut base to pull the cable bundle through the conduit. Once the cable bundle is routed into the strut base, it is then pulled through the instrumentation drip loop which enters the engine room at the instrumentation junction box.

12/19/78

Standard wire routing procedures will be followed throughout. Cable ties will be used to restrain and route the cables appropriately. Stainless steel tie straps may be used and spot welded to the structure where necessary. Appropriate care must be taken when using these straps so that the edges cannot cut or chaff the wires.

OK

In the event that the instrumentation conduit is not large enough, engineering liaison will be provided to establish alternate wire routing paths.

All wiring is to be identified, lugged, and connected to terminals in the junction box per a wiring diagram which will be provided by Engineering.

12/20/78

Reference Drawing 25-56169, Drip Loop Installation - Aft.

A. H. Rand For DON BLANCHARD
Instrumentation Engineer

Date: START 12/18/78
COMPLETED 12/20/78